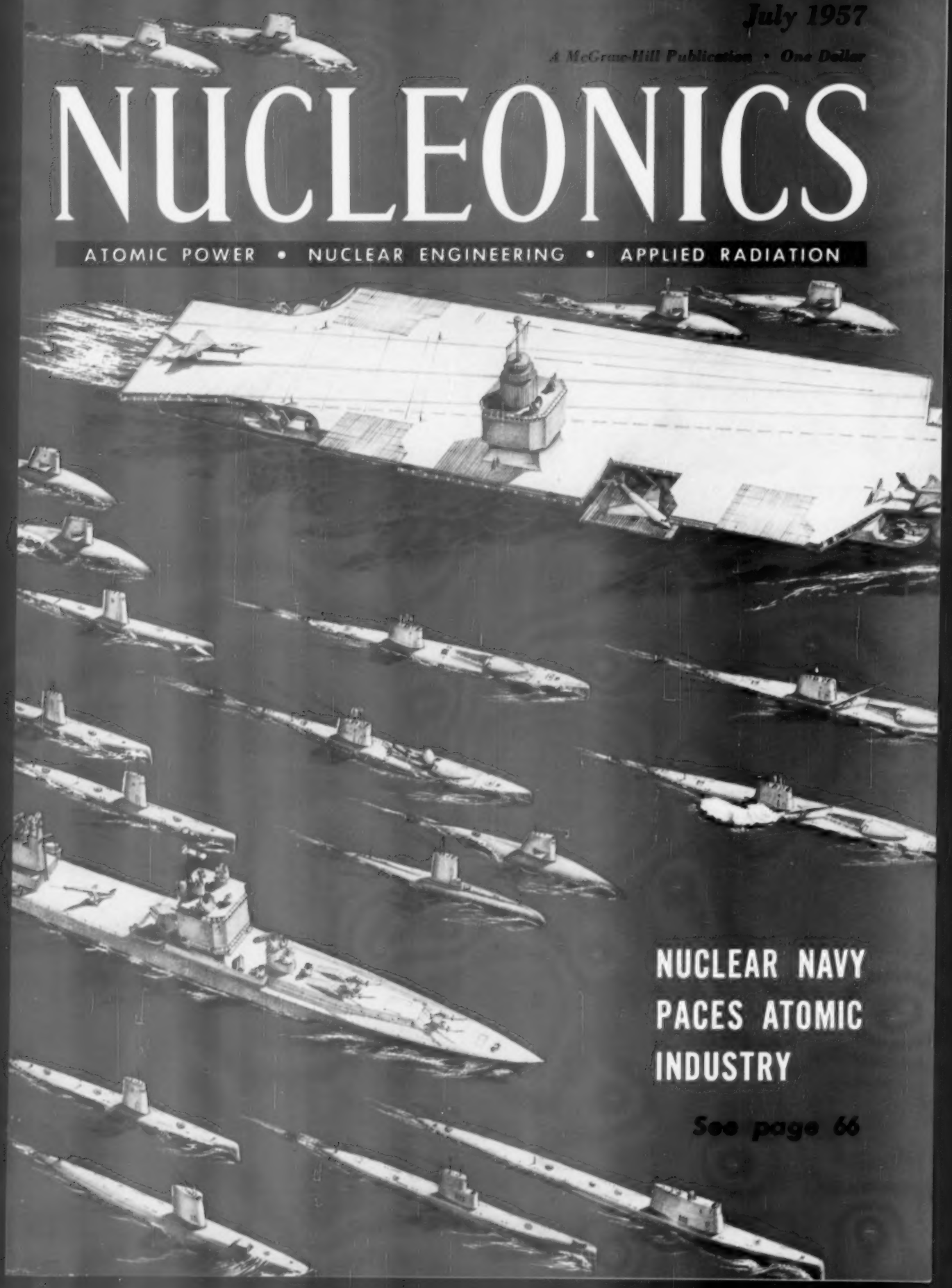
July 1957

A McGraw-Hill Publication • One Dollar

NUCLEONICS

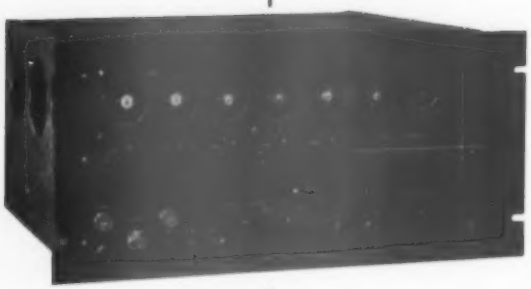
ATOMIC POWER • NUCLEAR ENGINEERING • APPLIED RADIATION



NUCLEAR NAVY PACES ATOMIC INDUSTRY

See page 66

3 NEW DEVELOPMENTS AT Hamner



DECADE SUPER SCALER
MODEL N-210

PHOTOMULTIPLIER PREAMPLIFIER
MODEL N-355

HIGH VOLTAGE POWER SUPPLY
MODEL N-413

For Improved Counting—
Check these OUTSTANDING FEATURES

DECADE SUPER SCALER MODEL N-210

- Response—1 μsec.
- Capacity—10^8
- Glow Tube Readout
- Input Sensitivity—Adjustable
- Minimum Pulse Width—0.1 μsec.
- High Input Impedance
- Preset Count—1000 to 9.9999 $\times 10^7$ Continuous
- At Customer's Option: Integral or Differential Discrim. Preset Time

PHOTOMULTIPLIER PREAMPLIFIER MODEL N-355

- For 6810 Phototube
- 20Ω Output Impedance
- Special Heat Sump Prevents Temperature Distortion of Photomultiplier Tube Operation
- 5 ma. Bleeder

HIGH VOLTAGE POWER SUPPLY MODEL N-413

- 200-5000 VDC Continuous
- 10 Milliamperes
- 0.005% Stability
- 0.001% Ripple at Full Voltage
- Standard Cell Calibration
- Positive or Negative Polarity
- Chopper and Voltage Amplifier Operated at Ground Potential

Prices Available Upon Request

Hamner

Hamner Electronics Co., Inc.
P. O. Box 531, Princeton, N. J. • Pennington 7-1320
West Coast Office: 944 Johnson Street, Redwood City, California

NUCLEONICS
ATOMIC POWER
NUCLEAR ENGINEERING
APPLIED RADIATION

VOLUME 15 NUMBER 7

H. W. Mateer, Publisher

Jerome D. Luntz, Editor

Daniel I. Cooper, Managing Editor
Thomas L. Cramer, Associate Editor
John E. Kenton, News Editor
R. Hobart Ellis, Jr., Assistant Editor
Harold L. Davis, Assistant Editor
Jesse S. Cook, III, Assistant Editor
Robert K. Otterbourg, Assistant Editor
Dimitrios Caratzas, Production Editor
Carol Williamson, Editorial Assistant
Patricia Simons, Editorial Assistant
Harry Phillips, Art Director
Roy Thompson, Assistant Art Director
G. B. Bryant, Jr., Chief Washington Bureau
V. Craig Richter, Washington Office
John Wilhelm, Chief World News Staff
London—W. J. Coughlin, John Tunstall
Paris—Robert E. Farrell
Bonn—Morrie Helitzer
Tokyo—Dan Kurzman
Rio de Janeiro—Peter Weaver
Mexico City—Jack Kearney
Melbourne—Alicja Grobtuch
Beirut—O. M. Marashian
Brussels—A. P. L. Gordon
Bombay—Sharokh Sabavala
Copenhagen—Else Balslev
Geneva—Ernest Hediger
Johannesburg—Ernest Shirley
Rome—Frank Gervasi
Stockholm—Curt Agren
Vienna—F. H. Baer
Keith Henney, Consulting Editor

●

James Girdwood,
Advertising Sales Manager
R. S. Quint, Assistant Advertising Sales Manager, Buyers' Guide Manager
Frederic Stewart, Promotion Manager
Frank H. Ward, Business Manger
Thomas Vought, Research
Wallace B. Blood, Market Consultant
Philip H. Hubbard, Jr., New York
Philip H. Hubbard, Jr., New England
James T. Hauptli, Philadelphia
B. Winner, W. Luce, W. Smith, Chicago
Warren H. Gardner, Cleveland
T. H. Carmody, R. C. Alcorn, San Francisco
Carl W. Dysinger, Los Angeles
D. Billian, M. Miller, Atlanta
G. L. Jones, E. E. Schirmer, Dallas
Herbert Lagler, London

CONTENTS JULY 1957

Experimental Boiling Water Reactor—A Special Report

Reactor File No. 1—EBWR facing 52
EBWR Operating Experience 53
Significance of EBWR 54
EBWR Power Costs 58
Starting Up EBWR JOSEPH W. HARRER 60

Feature Articles

Data Sheet No. 20—Gamma-Ray Streaming Through a Duct DAVID G. CHAPPELL 65
Nuclear Navy Paces U. S. Atomic Industry JOHN E. KENTON 66
New Ways in Isotopic Analysis of Uranium J. E. LOVETT and J. O. ROBERTS 72
Food Irradiation Reactor D. T. BRAY and C. P. LEYSE 76
Reactor Irradiator for Meat E. O. GUERNSEY and R. M. BALL 80

Cross Sections

Large-Sensitive-Area Portable Alpha Monitor F. D. RYDER and H. V. HARDISON 82
Simple Recording Gamma-Ray Spectrometer WILLIAM H. VENABLE, Jr. 84
Transistorized Photomultiplier Has 0.1-μsec Resolution G. S. BRUNSON 86
Rapid Method for Dating Nuclear Explosions SAIT AKPINAR 88

Nuclear Engineering

National Reactor Testing Station 90
Uranium Dioxide for Fuel Elements H. H. HAUSNER and R. O. MILLS 94
Applying Thermodynamics to Liquid-Metal-Fuel-Reactor Technology JAMES J. EGAN and RICHARD H. WISWALL, Jr. 104

Applied Radiation

Sinclair Facility Uses Spent MTR Fuel 108
Radiation Use Expanding 110

Departments

ROUNDUP 17
NUCLEAR ENGINEERING NOTES 92
BOOKS 112
LETTERS 114
PRODUCTS AND MATERIALS 116
NEWSMAKERS 122
NUCLEAR CALENDAR 124

More about NUCLEONICS on next page ▶

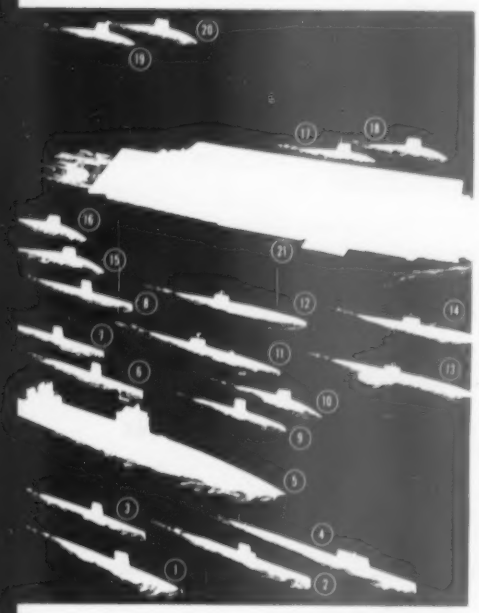
About NUCLEONICS

Something new has been added. For some time now we have been wrestling with the problem of how best to present information on completed reactors. Facing page 52 of this issue is the answer we have come up with. It is a six-page foldout devoted this month to the Experimental Boiling Water Reactor. In future months that same feature will be given over to other "Reactors on the Line."

In addition to providing a more effective and integrated mode of presentation of reactor information the new foldout is perforated for removal from the magazine and permanent filing. It is our hope that the full series will provide a convenient and comprehensive guide to reactor data.

As in any new undertaking lots of problems had to be overcome to bring this new series to fruition. Some of them were in the realm of content—what should be the level of such a piece? What should go into it? Other problems were mechanical—does the printer have the right size paper; will his bindery be able to handle this special insert. As this is being written some problems are still in the air but we don't lack confidence that you will find our new reactor descriptions as promised above.

As with all of our editorial material, special or otherwise, we would welcome your comments on our new foldout. Perhaps there are some things that you feel should be included in our table of properties. Perhaps you will have some suggestions for the difficult problem of best arranging the material content. We'd welcome hearing from you.



KEY TO NUCLEAR NAVY as displayed on cover.

1	Nautilus	12	SSGN
2	Seawolf	13	"
3	Skate	14	"
4	Triton	15	Skipjack class
5	Long Beach	16	"
6	Swordfish	17	"
7	Sargo	18	"
8	Leadragon	19	"
9	SIC	20	"
10	Skipjack	21	CVAN
11	Halibut		

•

This issue is late in reaching you because our master printers at Maple Press take their annual vacation during the week in which the issue normally comes out. We are sorry for any inconvenience this might cause you but know you will agree with us that Maple's fine job the year around makes them more than deserving.

•

Our salty cover. To do justice to presenting graphically the magnitude of the Navy's huge reactor program (see p. 66), our author, News Editor John Kenton, insisted on showing on one picture all the nuclear-propelled ships already built or authorized by Congress. Needing for this an outside artist we were very fortunate in being able to interest in this project a Navy artist, Mr. Robert R. Hays, who does architect's conceptions and other illustrative work for the Navy Department.

To help you identify the 21 ships built, building, or authorized thus far for the nuclear-powered navy we're provided a key at left.

As a staunch Navy man, Mr. Hays asked us to be sure to point out to our readers that the concentration of Navy power he depicted at our bidding would never really occur in maneuvers or battle in this atomic age. To avoid presenting so luscious a target, dispersal is the order of the day, and the ships of such a nuclear task force would in practice be so widely dispersed that from the bird's-eye distance of our cover only one ship would be visible—the others would all be off the page. —*The Editors*

ABC ABP NUCLEONICS (with which are consolidated "Atomic Power" and "Atomic Engineering"), July, 1957, Vol. 15, No. 7. Published monthly by the McGraw-Hill Publishing Co., Inc., James H. McGraw (1860–1948), founder. Executive Editorial, Circulating and Advertising Offices, McGraw-Hill Building, 330 W. 42nd Street, N. Y. 36, N. Y. Publication Office, 212 East York St., York, Pa. See panel below for directions regarding subscription or change of address. Donald C. McGraw, President; L. Keith Goodrich, Vice President and Treasurer; John J. Cooke, Secretary; Nelson Bond, Executive Vice President, Publication Division; Ralph B. Smith, Vice President and Editorial Director; Joseph H. Allen, Vice President and Director of Advertising Sales; A. R. Venezian, Vice President and Circulation Coordinator. United States subscription rate for individuals in the field of the publication $8 per year; Canada, other Western Hemisphere countries, and the Philippines, $10 for 1 year; all other countries, $15 for 1 year. Single copy prices: United States, United States possessions and Canada, $1; elsewhere, $2. Position and company connection must be indicated on subscription orders. Second-class mail privileges authorized at York, Pa. Printed in U. S. A. Title registered in U. S. Patent Office. © Copyrighted 1957 McGraw-Hill Publishing Co., Inc., all rights reserved.

SUBSCRIPTIONS: Send subscription correspondence and change of address to Subscription Manager, NUCLEONICS, 330 West 42nd Street, New York 36, N. Y. Subscribers should notify publisher promptly of any change of address, giving old as well as new address, and including postal zone number, if any. If possible, enclose an address label from a recent issue of the magazine. Please allow one month for change to become effective.

Postmaster: Please send form 3579 to NUCLEONICS, 330 W. 42nd St., N. Y. 36, N. Y.

Coming Features in NUCLEONICS

Next Month - Reactor File No. 2 Army Package Power Reactor

Fission-Plasma Reactor

Report on American Nuclear Society Meeting

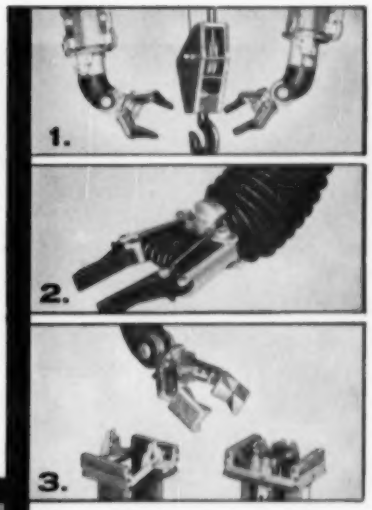
Later Months - Fuel Reprocessing Series

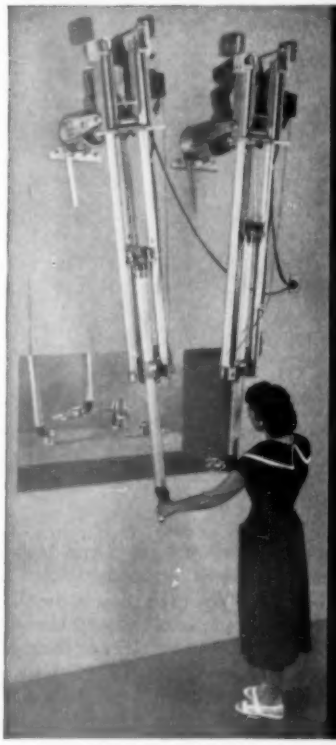
Tenth Anniversary Issue

French Reactor Instrumentation

you can **feel** *the difference in the CRL system*

The "sense of feel", the versatility, the uncompromising workmanship . . . all are found in every CRL Manipulator. Research and production organizations all over the world are using these units for handling radioactive materials, explosives, and hazardous chemical and biological materials. Natural motions of the operator's hands are copied exactly at the slave end. The "sense of feel" helps the new operator to become perfectly competent with practically no training period. Handles are adjustable to comfortably fit a wide range of hand sizes.

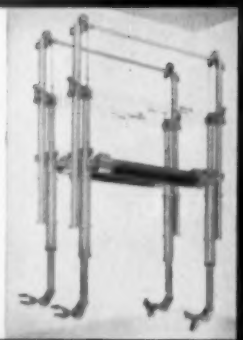




CRL Model 4

for over-wall installation

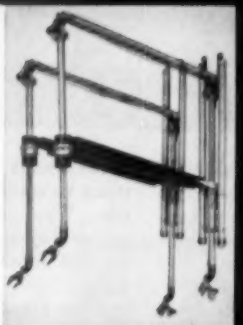
A general purpose manipulator for installation over a barrier wall or through a ceiling opening of a protective enclosure.



CRL Model 7

for restricted space installation

A space conserving, light weight manipulator for use in hoods or over thin walls where minimum clearances and easy portability are important factors.



1. *Cranes and hoists* For moving heavy loads in hot cell areas by remote control. They are specially designed by CRL for use with CRL manipulators.

2. *Flexible booting* Protects slave end from dust and contamination. Restricted gas-flow seal possible. Won't interfere with manipulator's natural movements.

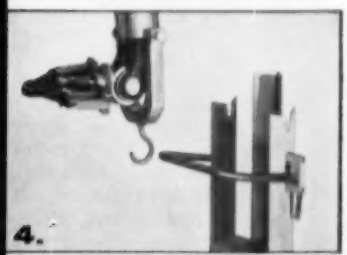
3. *Special-purpose tongs* For repetitive or highly specialized operations. Wide selection of types to meet all requirements.

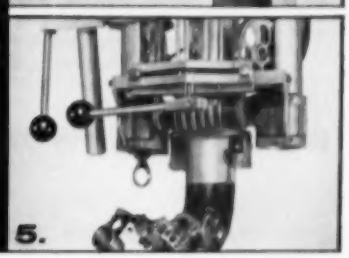
accessories

for master-slave manipulators

4. *Load hook* Available for CRL Model 8; may be remotely attached or removed. Permits a vertical lift of 60 lbs.

5. *Motion locks* Permit objects to be rigidly positioned in space. *Locking grip* standard on all models. Locks for all other motions available as accessories.





CRL Model 8

for thru-wall installation

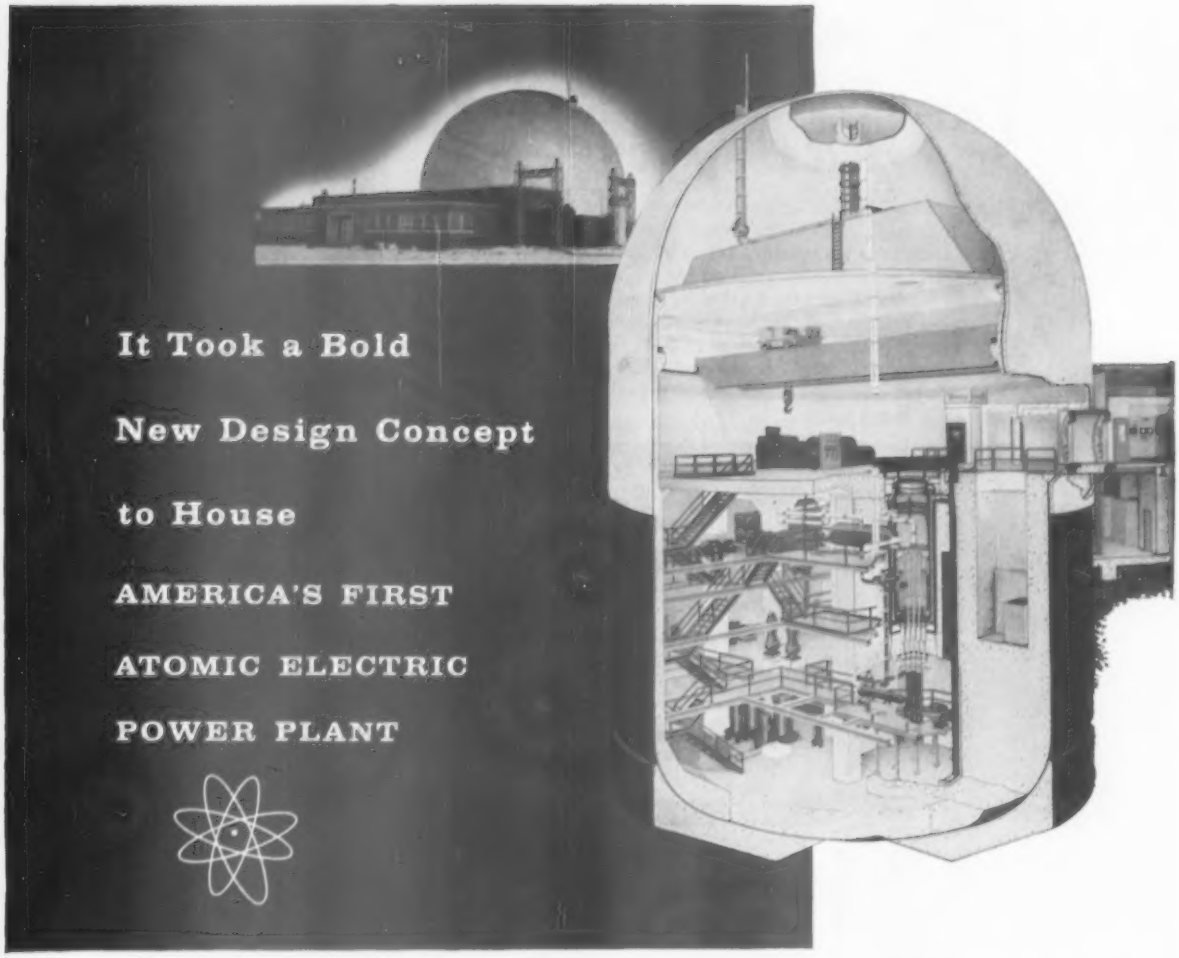
A general purpose manipulator for installations requiring intermediate to high level shielding, the Model 8 features

- *Accurate "sense of touch"* Low friction forces . . . low backlash . . . low inertia
- *Greater versatility* A variety of tools, tongs and locking motions available
- *Easier sight control* Operator need not step back to bring materials to barrier window
- *Ease of relocation* Can be withdrawn and moved by one man in five minutes with a light crane

central research manipulators
from basic Argonne National Laboratory design

write today for complete information to:

Central Research
laboratories, inc.
Red Wing, Minnesota
Dept. 102



How do you house an atomic electric power plant? Dig a hole five stories down. Erect a giant ten-story welded steel "containment vessel." Seal it off air-tight, and you have one of the largest pressure vessels man has ever been called on to build.

That's the story, over-simplified, of the unique housing required for America's first nuclear-powered electric plant, the Experimental Boiling Water Reactor, at Argonne National Laboratory, Lemont, Illinois.

In our practical, efficient world of engineering, there is a sound structural reason for the unusual dome-shaped building, now recognized by everyone as the symbol of atomic-power-for-peace.

Radioactive steam and gases must be contained within the system. The precautions necessary demanded an air-tight building, 80 feet in diameter by 119 feet high.

This giant welded steel structure, designed to withstand a pressure of 15 pounds per square inch above gage pressure, was made concave throughout, with a semi-ellipsoid bottom and a hemispheric top.

Upon completion, the half-million cubic foot shell was tested for air-tightness. Never before had so large a welded structure required such thorough testing against air loss.

Graver's skills, backed by a century of experience, were called upon to fabricate, erect and test this unique steel structure.

Graver's research department devised the special air-tightness testing procedures. Graver fabricated all sealing devices—the access air-locks, bulkheads and doors, and the two water-demineralizing systems. It also furnished the saucer-shaped 15,000 gallon water tank suspended under the dome.

This application of Graver's skills in the fabrication and erection of America's first atomic power plant is indicative of Graver's readiness to help you fulfill your plans for the future, no matter how unusual or exacting the requirements.

Building for the Future on 100 Years of Craftsmanship in Steels and Alloys

GRAVER TANK & MFG. CO., INC.

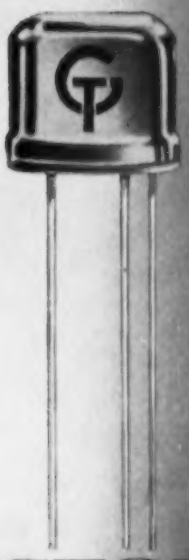
EAST CHICAGO, INDIANA • NEW YORK • PHILADELPHIA • EDGE MOOR, DELAWARE
PITTSBURGH • DETROIT • CHICAGO • TULSA • SAND SPRINGS, OKLAHOMA
HOUSTON • LOS ANGELES • FONTANA, CALIFORNIA • SAN FRANCISCO

GRAVER

miniaturization with reliability for UNIVERSAL ATOMICS®

Achieved by

GENERAL TRANSISTOR



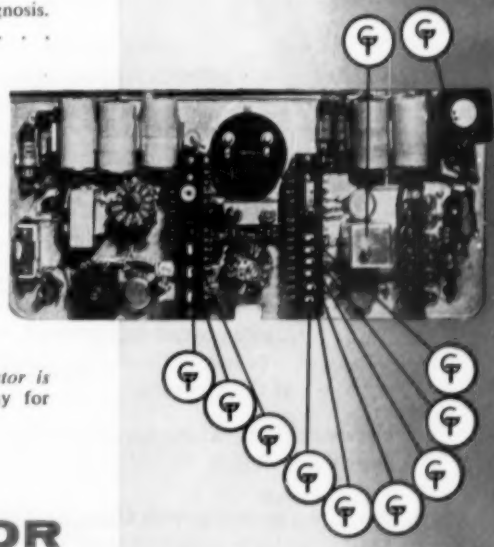
VERSATILE. TRANSISTORIZED UNIT ENABLES FASTER. MORE RELIABLE MEDICAL ANALYSIS

The design problem confronting Universal Atomics, for the UAC 522 Ratemeter, was to produce a completely miniaturized, compact portable unit using low-power consumption at a realistic price. The unit is intended for use in both clinical and medical radioisotope research and diagnosis. A reliable miniaturized circuit was essential . . . GT was called in.

General Transistor's engineering department recommended the GT-20 P-N-P type. This reliable audio transistor offered a current gain range of 35-50, maximum noise figure of 16 db., and a collector-base voltage of 25 volts. The equipment using these transistors continued to perform with extreme accuracy, even when exposed to severe environmental conditions.

All GT transistors must pass strict quality controls, production line testing plus a 100% final inspection . . . your assurance of a completely reliable product.

This is just one more example why *General Transistor is the fastest growing name in transistors.* Send today for Bulletin G-110.



GENERAL TRANSISTOR
CORPORATION

91-27 138TH PLACE JAMAICA 35, NEW YORK

To **engineers** whose present jobs seem to end where they begin...

AT DOUGLAS, YOUR ASSIGNMENTS HAVE THE SCOPE THAT LETS YOU PROGRESS AT YOUR OWN PACE!

Going around in circles? Chances are your present job has become too routine. At Douglas, long-range projects of tremendous scope assure a constant variety of assignments . . . and the opportunity to expand your responsibilities. Douglas is headed by engineers who believe that promotion must come from within. They'll stimulate you to build a rewarding future in your field. For example, here are . . .

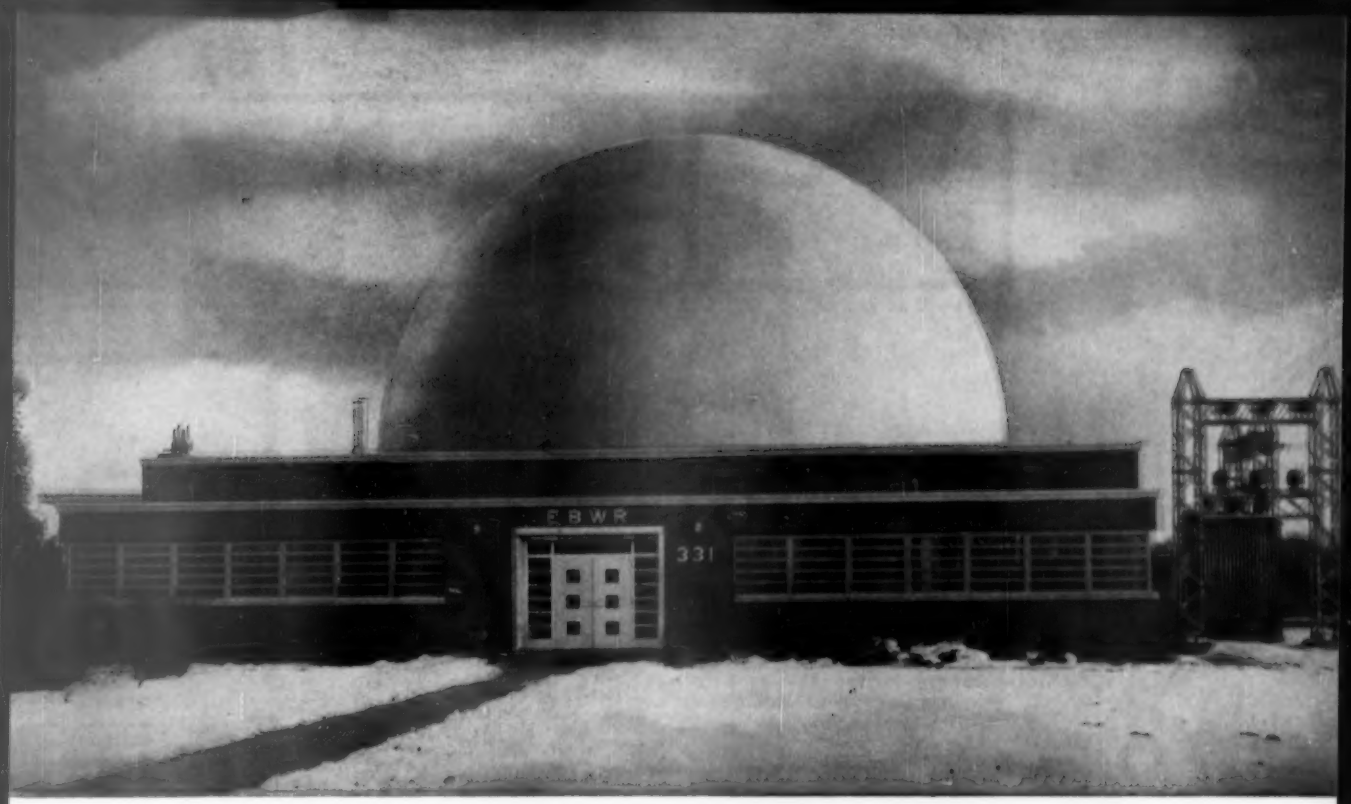
CAREER OPPORTUNITIES FOR STATIC AND DYNAMIC TEST ENGINEERS! Aeronautical and Mechanical Engineers conduct ground, wind tunnel and flight tests to insure the design integrity of the aircraft.

For important career opportunities in your field, write:

C. C. LaVENE
DOUGLAS AIRCRAFT COMPANY, BOX L-620
SANTA MONICA, CALIFORNIA

Go further with DOUGLAS

FIRST IN AVIATION



EBWR

"Today marks an event of historic significance in man's development of the atom for peaceful purposes. The reactor we are placing in operation today is the first of a generation of such reactors designed to provide electric power for our factories and our homes, power upon which the strength and future well being of this country vitally depends."

from Dedication address, Feb. 9, 1957, by Rep. Carl T. Durham, Chairman, Joint Congressional Committee on Atomic Energy.

EXPERIMENTAL BOILING WATER REACTOR PLANT

Argonne National Laboratory
Lemont, Illinois

TURBINE RATING
5000 kw—600 psig—488° F

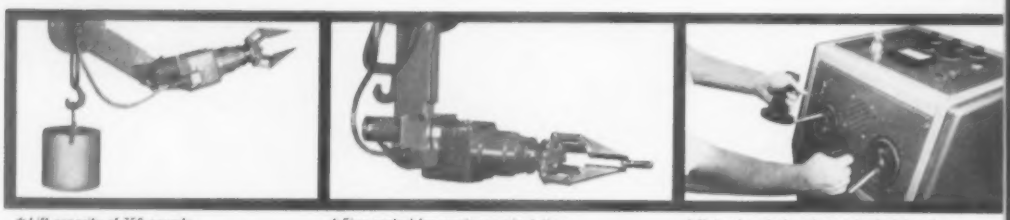
ENGINEERING AUTHORIZED
August 25, 1954

FULL POWER GENERATION
December 29, 1956

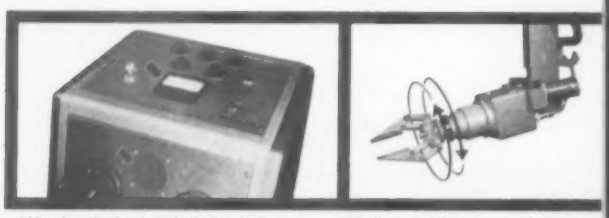
FORMAL DEDICATION
February 9, 1957

SARGENT & LUNDY ENGINEERS

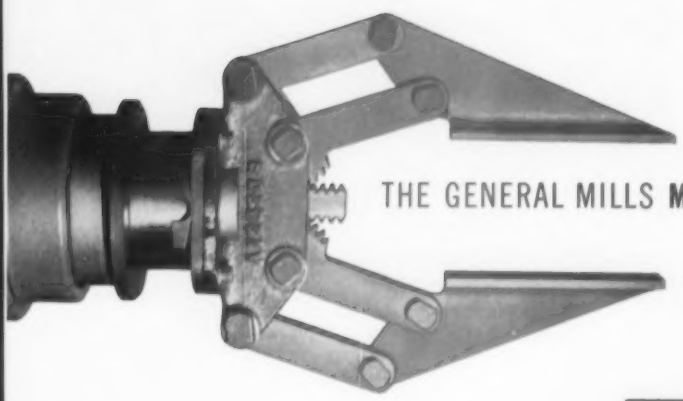
140 SOUTH DEARBORN STREET, CHICAGO 3, ILLINOIS



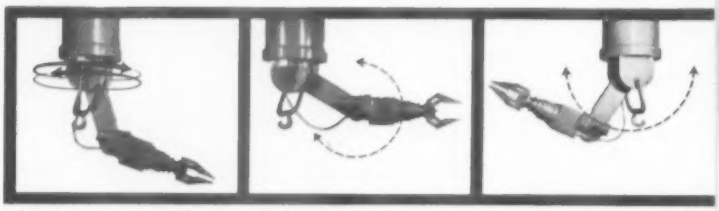
* Lift capacity of 750 pounds.
* Fine control for precise manipulations.
* Natural controls cut operator training time.



* Visual-audio signals to indicate grip force.
* Continuous, right or left, wrist rotation.



THE GENERAL MILLS **MECHANICAL ARM** IS THE ONLY REMOTE-CONTROL MANIPULATOR TO GIVE YOU **ALL** THESE FEATURES*

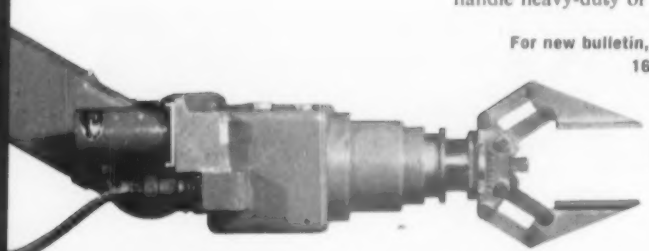


* Continuous rotation of entire arm.
* Forearm bends 220 degrees
* Swings through 180 degree arc.

* Holds position with hands off controls.
* Simple electrical linkage permits mounting on crane or vehicle for complete mobility.
* Adaptable to telescopic and television viewing for "limitless" reach.
* Complete line of tools, remotely interchangeable.

About to buy your first remote-control manipulator? Thinking of installing an additional one? In either event, get the facts about the General Mills Mechanical Arm first. Here's a manipulator that can handle heavy-duty or precise manipulations without modification or adjustment between operations. Its unusual mobility and ease of control make it even more desirable for "hot lab" installations. Other exclusive features merit your investigation as well.

For new bulletin, write Department N7, Mechanical Division of General Mills, 1620 Central Avenue, Minneapolis 13, Minnesota



MECHANICAL DIVISION General Mills

Creative Research and Development
Precision Engineering and Production

tt
TUBE-TURN
TRADE MARKS

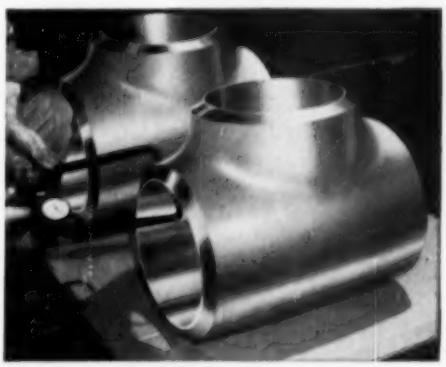
Seamless stainless-clad carbon steel 52" elbow for pressurized water reactor.

SEAMLESS stainless-clad carbon steel

...another Tube Turns' first in nuclear reactor fittings

These heavy-wall stainless-clad carbon steel elbows are typical of a line of seamless welding fittings pioneered by Tube Turns for nuclear reactors. Provides the corrosion-resisting properties of stainless steel at lower cost than solid stainless steel.

Tube Turns is also producing seamless, forged fittings in stainless steels, chrome-moly steels, aluminum and titanium for reactor piping. For consultation on nuclear power piping problems, call the nearest Tube Turns' office.



TUBE-TURN stainless steel welding tees for a two-reactor submarine.*

The Leading Manufacturer of Welding Fittings and Flanges

TUBE TURNS LOUISVILLE 1, KENTUCKY

A Division of National Cylinder Gas Company

DISTRICT OFFICES: New York • Philadelphia • Pittsburgh • Chicago • Detroit • Atlanta • New Orleans • Houston • Midland Dallas • Tulsa • Kansas City • Denver • Los Angeles • San Francisco • Seattle

In Canada: Tube Turns of Canada, Ltd., Ridgetown, Ontario • Toronto, Ontario • Edmonton, Alberta

*"TUBE-TURN" and "tt" Reg. U. S. Pat. Off.

AN EFFECTIVE WAY TO DEVELOP VALUABLE GOOD WILL FOR YOUR COMPANY

. . . and help to do a life-saving job at the same time

You can achieve lasting good will for your company—the kind of good will that results in friendly relations with every group in your community. And you can help to save precious lives at the same time, by putting your company's efforts behind the nation-wide campaign against traffic deaths.

During 1956, the national total of highway deaths was over 40,000—the highest figure in our history. The cost to the country of these wasted lives is incalculable.

But the picture wasn't entirely black. In many areas—in small towns and big cities—the terrible upward trend was reversed.

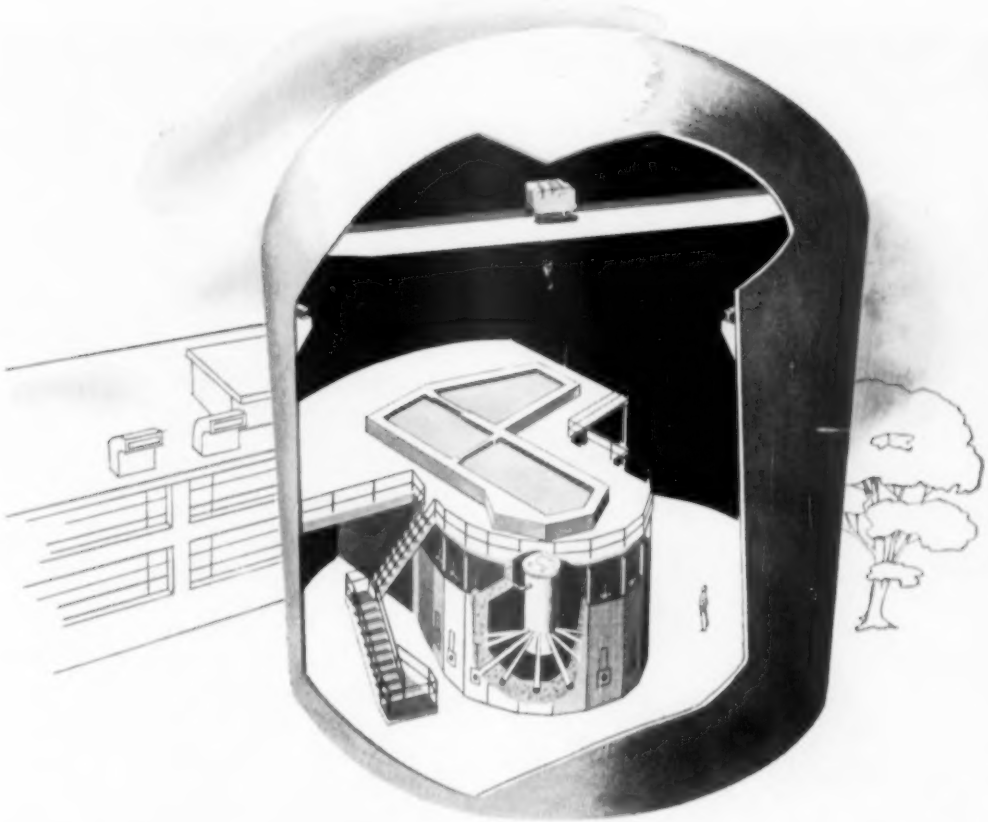
This was accomplished by community action—by business leaders, civic organizations, church, fraternal and PTA groups joining together with law enforcement agencies in an all-out attack on traffic deaths.

The figures prove it. Wherever people get together to do something about traffic safety, *deaths go down.*

BACK THE ATTACK ON TRAFFIC ACCIDENTS!

Your company can perform an invaluable service for your community, and for the country as a whole, by pitching in and helping in this life-saving crusade. For full information on what you can do — and how you can do it—write The National Safety Council, Chicago 11, Illinois.

Published in cooperation with
The National Safety Council
The Advertising Council



REACTOR CENTRUM NEDERLAND

acf supplies 20,000 kw light water reactor

Now being designed and fabricated by acf Industries, Incorporated, the 20,000 kw light water reactor facility for the Reactor Centrum Nederland will be used for a broad range of research and development programs in nuclear science and technology.

Experimental facilities include 12 ports, four rabbits and one irradiation facility adjacent to the core region. Average thermal flux in the core will be 1.38 x 10^{14} n/cm^2/second. Reflector elements are beryllium, designed to be interchangeable with fuel elements.

Nuclear Products-Erco Division is staffed and equipped to design and build complete reactor facilities for power, research, materials testing, and other purposes. We cordially invite inquiries relating to design and manufacture of reactors, components, and associated equipment.

Engineers and scientists interested in joining this well-staffed and well-supported group are invited to inquire about the many available opportunities.

acf REACTORS
currently under design and construction

1,000-5,000 kw heavy water research reactor for the Massachusetts Institute of Technology.

5,000 kw heavy water research reactor for the Italian National Committee on Nuclear Research.

20,000 kw light water materials testing and research reactor for Reactor Centrum Nederland.

30,000 kw light water materials testing and research reactor for Aktiebolaget Atomenergi of Sweden.

10,000 kw light water materials testing reactor for the Nuclear Engineering Test Facility, Wright-Patterson Air Force Base, Ohio.

A preliminary design of a 10,000-20,000 kw light water materials testing reactor for the Case Institute of Technology.

acf **nuclear products-erco**

Division of acf Industries Incorporated, 508 Kennedy Street, N.W., Washington, D.C.

Not alike at all!

Eventually, two peas in a pod may not be alike at all!

By the time they reach tomorrow's dinner tables, one may be irradiated, the other may not.

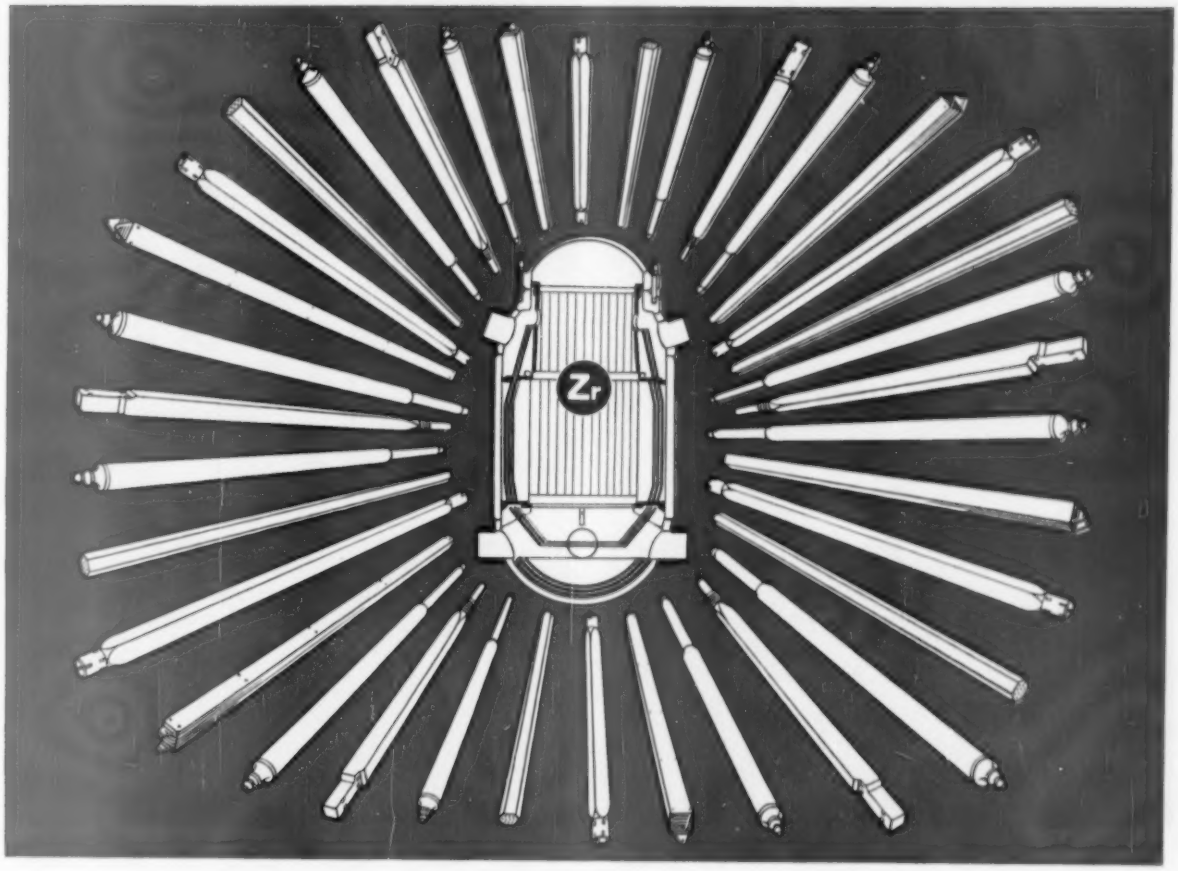
We at Nuclear Systems are vitally interested in food irradiation. Fact is, we're vitally interested in radiation applications as diverse as the synthesis of chemicals, the polymerization of synthetic resins and the vulcanization of rubber.

Nuclear Systems can provide a *complete* radiation package—equipment, instrumentation, training, facility design and sources of cobalt 60 up to 50,000 curies.

NUCLEAR SYSTEMS

A DIVISION OF THE BUDD COMPANY, Philadelphia 32

Budd



WCC ZIRCONIUM

...in production now!

High-Purity Sponge Available for Prompt Delivery In Reactor or Research Quantities

ZIRCONIUM is no longer a metal of tomorrow . . . Wah Chang Corporation alleviates your supply problem, **today!**

Increased new manufacturing facilities in Oregon make WCC one of the leading commercial producers of ZIRCONIUM . . . a **dependable** source for this critical nuclear and structural metal . . . one you can rely on for competitive pricing and on-time deliveries of both reactor and commercial grade sponge.

WCC ZIRCONIUM has the uniformity, exceptional ductility and excellent corrosion resistance needed to fulfill the requirements of such exacting applications as: control rods, pressure vessels and fuel rods. These qualities are **assured** by WCC's extensive metallurgical experience and strict controls over **every** manufacturing process from sand to sponge.

Inquiries about prices, delivery dates and technical assistance are welcome.

More WCC Metals are on the way . . . look for them.

WAH CHANG CORPORATION

WOOLWORTH BUILDING, NEW YORK 7, N. Y.

BRINGING TOMORROW CLOSER WITH NEW METALS

Robert Rossler, FICo engineer, holding plug-in analog modules — a transistorized amplifier unit and an electro-mechanical unit. Electronic panel of analog computer is in background.

FICo digital engineer Peter Carbone holding digital module, comprised of easily removable transistorized printed circuits. Rack-type digital computer is in background.

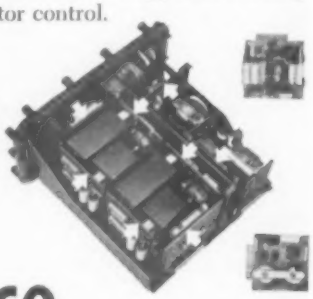
ANALOG or DIGITAL:

WHICH TYPE OF SPECIAL-PURPOSE COMPUTER IS BETTER?

THE ANSWER: ***It depends on the application.***

Ford Instrument develops and produces *both* types of computers — analog and digital — for an unlimited range of systems applications. FICo analyzes the problem and designs the computer best suited to the needs of the application, in terms of reliability, flexibility, economy, and size. For both types of special-purpose computers FICo employs modular techniques, simplifying the problems of design and manufacturing . . . and making servicing fast, simple, and economical.

FICo has developed and produced special-purpose computers to handle an extreme variety of problems — including missile and rocket launching, missile guidance, airborne and tank navigation, test and other data processing, degaussing, torpedo launching, gunfire control, and many others. This technology is now being applied by FICo to reactor control.



FICo modular techniques as applied to an amplifier for an airborne navigational system. Arrows point to printed circuit amplifiers. Two typical cards are shown at right.

FORD INSTRUMENT CO.

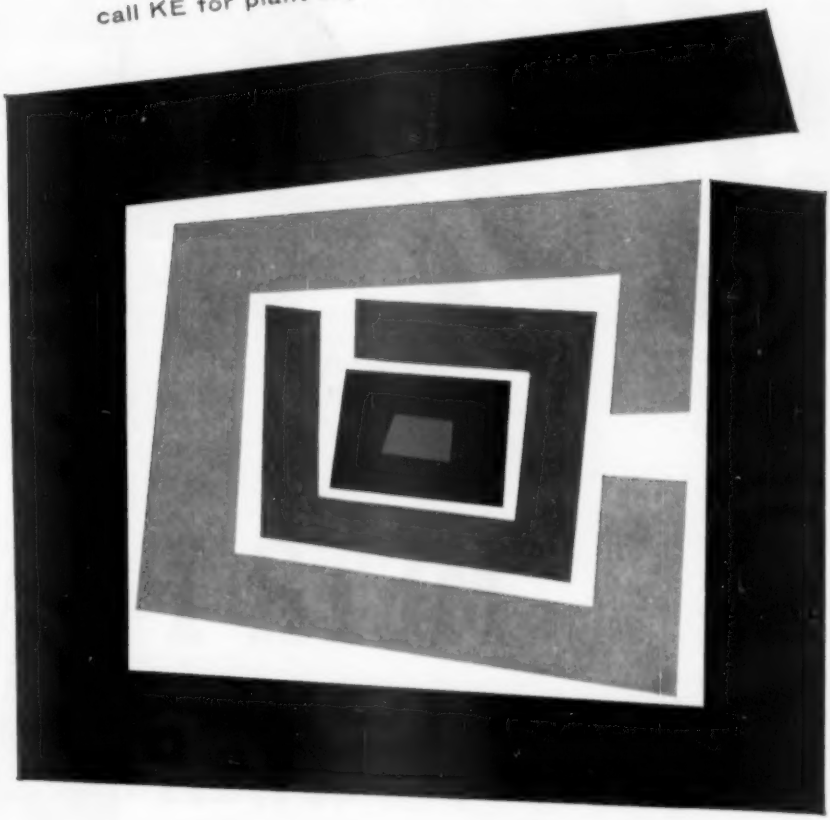
DIVISION OF SPERRY RAND CORPORATION

31-10 Thomson Avenue, Long Island City 1, New York

Beverly Hills, Calif. Dayton, Ohio

ENGINEERS of unusual abilities can find a future at **FORD INSTRUMENT CO.** Write for information.

call KE for plant expansion or new facilities



call KE for plant expansion or new facilities

call KE for plant expansion or new facilities

INGENUITY

has made KE the experienced leader in nuclear projects

Engineering Test Reactor, National Reactor Testing Station, Idaho. Designed and built by KE—on schedule and within estimate!

The Engineering Test Reactor, Food Irradiation Reactor, Hanford Production Reactors, Aircraft Nuclear Propulsion Testing Facilities—these represent some of the nuclear energy projects performed by Kaiser Engineers. In each case, KE ingenuity produced efficient, lower cost facilities.

KE's Nuclear Engineering Division has the highly specialized skills and experience required to undertake complete design and construction of nuclear research, production or power generating facilities. Call KE for planning or building your nuclear project.

KAISER ENGINEERS engineers—contractors
Contracting since 1914

Kaiser Engineers Division of Henry J. Kaiser Company • Oakland 12, California • New York, Pittsburgh, Washington, D.C., Buenos Aires, Calcutta, Dusseldorf, Montreal, Sydney, Tokyo

NDA-V

METR I

A NEW MATERIALS and ENGINEERING TEST REACTOR by *NDA*

NDA has now completed preliminary design of Materials Engineering Test Reactor I for construction at Mol as Belgian Reactor II. Joined by senior personnel from CEAN, *NDA* is now carrying out detailed design. *NDA* believes METR I will be of interest to nuclear engineers and scientists throughout the world. Consider these characteristics:

- **Thermal power level: 50 MW**
- **Available core neutron flux during experiments**
  Fast . . . . . 2×10^{15} n/cm²/sec
  Thermal . . . 6×10^{14} n/cm²/sec
- **Single fluid—light water cooling**

Consider also the flexibility of METR I:

- **Five 8½" through holes in core section**
- **Central irradiation tubes in each fuel element**
- **Forty 3½" holes in core matrix (including 10 through holes)**
- **Six 1" rabbit tubes**
- **Seven radial beam holes up to 12" in diameter**
- **Four tangential beam holes up to 12" in diameter**
- **Reactor pool space for irradiation of large equipment**
- **Core mock-up facility**
- **Gamma irradiation facility**
- **Individual access to each fuel element and beam hole**

With its high available neutron flux, flexibility and ease of access, METR I is unsurpassed as a test reactor.

Opportunities exist at *NDA* for qualified scientists and engineers interested in reactors of advanced design for research, power and propulsion.

For information write or call

NDA_ **NUCLEAR DEVELOPMENT CORPORATION OF AMERICA**

5 NEW STREET, WHITE PLAINS, N. Y. · TEL. WH 8-5800

ROUNDUP of Key Developments in Atomic Energy

Murray Named Consultant To Congress' Committee

Effective July 1, the day after his term as an AEC member expired, Thomas E. Murray became a consultant to the Joint Committee on Atomic Energy.

JCAE Chairman Durham said Murray's appointment "will ensure that his eminent qualifications will be available to this nation." Certain it is that Murray with his inside knowledge of the Commission will be an invaluable asset to JCAE on those occasions when it is at odds with AEC, prodding for more reactor building or for fuller information. Some Democrats commented privately that, with the weight of Congress behind him, Murray may actually be more successful in getting information than he had been as an AEC member.

Floberg and Graham, Truman Aides, Named to AEC; Murray Out, Fires Parting Blast at Present Policy

In a bold unexpected move, the Administration met the gathering crisis over the Murray reappointment head-on by naming two Truman sub-Cabinet officials to the AEC.

• To succeed Thomas E. Murray, whose term expired June 30, the President named to a full five-year AEC term **John F. Floberg,** 41, Washington lawyer formerly from Chicago, graduate of Loyola Univ. and law review editor at Harvard Law School, Navy combat officer during World War II at Sicily, Salerno, Philippines, Iwo Jima, Okinawa; Assistant Secretary of the Navy for Air from 1949 to 1953. In the latter position he was in charge of Navy research and development and was involved in construction of *Nautilus*. He calls himself a political independent.

• To fill the unexpired term of the late John von Neumann, which runs until June 30, 1959, the Chief Executive selected **John S. Graham,** 51, Washington financial and business consultant, graduate of North Carolina Univ. and the Univ. of Virginia Law School, pre-war Winston-Salem lawyer, Navy officer in the war serving in the office of the Deputy Chief of Naval Operations for Air, Assistant Secretary of the Treasury from 1948 to 1953. He is a Democrat who was national treasurer of Volunteers for Stevenson in 1956.

Hearings in the Senate on their confirmation are not expected to be scheduled until late this session.

Chairman Carl T. Durham (Dem., N. C.) of the Joint Committee on Atomic Energy described both appointments as "very good," but said he was "disappointed" that Murray had not been renamed—a reaction promptly echoed by other JCAE Democrats such as Clinton P. Anderson and Albert Gore.

Politics at Play

Even though both men served in the last Democratic administration, many observers foresaw trouble on confirmation in the Senate—so strong has been the sentiment for reappointment of Murray. The latter's clashes with AEC chairman Lewis L. Strauss over Commission policies, however, have been heated and frequent, and Strauss—who is also the President's atomic energy adviser and who undoubtedly played a key role in the selection of the candidates—was not expected to acquiesce in Murray's retention. Democrats and some Republicans nevertheless urged it, regarding the need for an independent voice on the Commission of top importance.

Many had thought that under the circumstances, the Administration would choose to play an end run: wait for Congress to adjourn, make recess appointments, and confront the second session of Congress in January with the *fait accompli* of

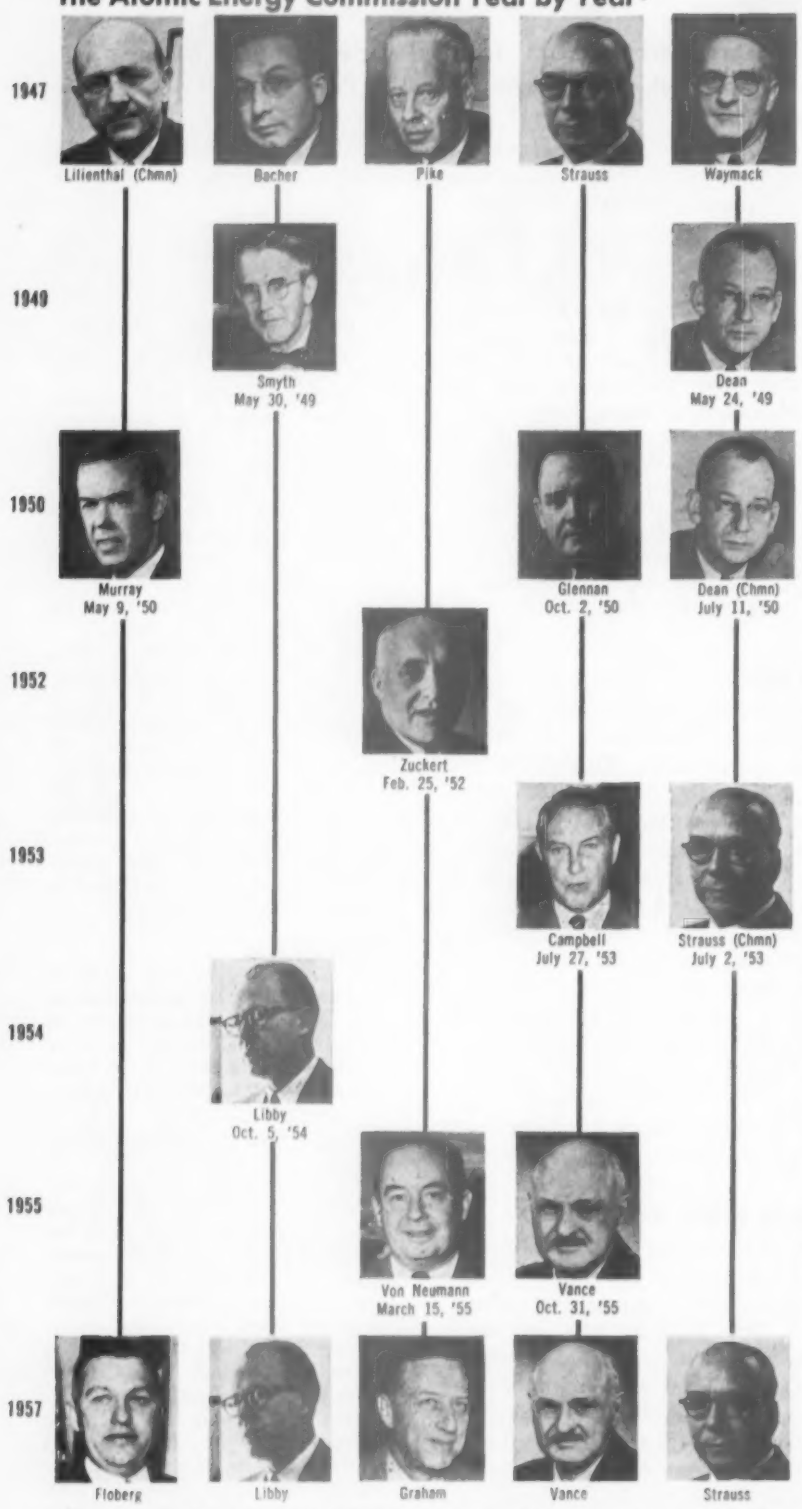
House passes Federal indemnity bill

On July 1 the House passed by divided voice vote and sent to the Senate a bill for Federal indemnity insurance up to $500-million on each reactor project licensed by AEC. The bill differs from the one that failed of passage last year (NU, June '56, 20B; Aug., R1) in two significant ways: First, coverage is charged for in the case of Section 103 (proven commercial value) reactors, at $30/yr/Mw of thermal energy capacity. AEC may set lower rates for Section 104 (developmental) reactors. A minimum fee of $100/yr is set. Second, the Advisory Committee on Reactor Safeguards is made a statutory committee and its reports are required to be made public. Rep. Chet Holifield (Dem., Calif.), who led limited opposition to the bill, lost in a move to make safeguards committee approval a prerequisite for nuclear power plant construction. Holifield fought the bill on the ground it would "provide another government subsidy" without commensurate benefits to taxpayers, and would saddle "an enormous potential liability" on the government without knowledge of how safe reactors are.

First plutonium core use stymied by EBR-1 meltdown

A reactor core of plutonium fuel elements—world's first—was fabricated for use in EBR-1 and was to have gone into the experimental breeder when the latter's second uranium core melted down (NU, May '56, 17; Jan. '57, 84). Built for AEC by Dow Chemical Co. at its Rocky Flats, Colo., remote-handling facility, the Pu core has been mostly in storage; a part was used briefly in ZPR-3 for Doppler measurements. It is now being refabricated for use as a complete ZPR-3 core. AEC still intends eventually to put a plutonium core in EBR-1, after completion of the presently-scheduled EBR-1 tests with rigid and non-rigid fuel pins to determine the role of pin bowing in causing the meltdown. But for now, Argonne Laboratory has its hands full with those tests.

The Atomic Energy Commission Year by Year*



* The five members of the original Commission were named in recess appointments by President Truman on Oct. 28, 1946, and took office within the week. The date given for subsequent appointees is the date of swearing in, following Senate confirmation. Allen Whitfield was named in 1955 to succeed Joseph Campbell, but withdrew before confirmation hearings had been set.

new Commissioners in office for 5–6 months. That instead the Administration made a frontal charge on the Murray partisans—called a linebuck over center, so to speak—may be taken as indicative of its confidence that its two candidates are of a caliber that the Murray forces cannot gainsay.

Industry observers were curiously awaiting one thing last month: to see whether the new appointees would be able to function as independent-minded Commissioners. This was not to question the strength of character of the two men. Rather it was an awareness that although both had long backgrounds in governmental, legal and financial work, neither has had extensive contact with the atomic energy field; a recognition that it would consequently take them 6–12 months to learn all the angles and interrelationships; and—on the part of some anti-Strauss elements—fear that they won't learn enough to stand on their own two feet. On the other hand former associates said Floberg and Graham "won't carry anybody's baggage." One prominent person in the field regretted that men who had been living with atomic energy and wrestling with its problems were not named, while another said, "I don't know where we'd have found better ones."

Willard F. Libby now remains the lone scientist on the five-man board, as had been the situation in the earlier days of the Commission when first Robert Bacher, then Henry D. Smyth had been the scientific member. During 1955–56 Libby and Von Neumann had given top AEC leadership two scientific heads, so to speak. (There is of course no hard and fast rule on this, it being merely a kind of unwritten law that there be at least one scientist on the Commission.)

In a parting blast at AEC policies, Murray—whose seven years on the Commission added up to the longest consecutive tenure in its history—filed a 25-page critical report with JCAE. Most of his strictures dealt with weapons policy, but he also renewed his pleas for a big government program of building large power reactors, and for an end to "antiquated and unsatisfactory" secrecy policies. Reliance on private industry to develop nuclear power has proved ineffective, he said, and will not suffice if the U. S. is to take the lead in promoting an international atomic energy economy.

AEC Loses Reactor Program Control to Congress

Giving in to Democratic demands, AEC last month agreed to Congressional control over the power reactor development program.

And, in line with Congress' desire to bring AEC activities under closer public inspection, the Commission made its first public appearance before a Congressional committee in support of its program.

Specifically, the Commission appeared to seek authorization, item by item, for projects in its civilian reactor program which would require $147-million in funds.

Once the authorizations are signed into law, AEC must then put these projects through the appropriations procedures of the House and Senate to secure the funds needed to carry them out. As far as reactors are concerned, this procedure puts AEC on much the same footing as the Bureau of Reclamation, Corps of Engineers, and other bodies that must justify each project to Congress.

The procedure was quickly voted into law last month. The haste was to forestall possible complications and delays in obtaining subsequent appropriations, as threatened by Rep. Clarence D. Cannon (D-Mo.), (NU, May '57, 18). Chairman Carl T. Durham of the Joint Committee on Atomic Energy and Sen. Clinton P. Anderson, (D-N. M.) sponsored the measure amending Sec. 261 of the 1954 Act to require this routine henceforth.

Not only AEC, but also the sponsors of various reactor projects testified before JCAE. The authorizations sought were for research, development and construction funds for projects in the first, second and third round invitations.

Actually, the $147-million breaks down to $123.8-million that would have to be appropriated, and $23.1-million representing waiver for fuel use charges, requiring no payouts.

The projects are: Power Reactor Development Co. ($4.2-million); Consumers Public Power District ($44.2-million); Elk River Rural Cooperative Power Assn. ($8.4-million); Wolverine Electric Cooperative ($4.9-million); City of Piqua, Ohio ($7.5-million); Chugach Electric Ass'n. ($13.6-million); post-construction r-&-d expenses under second round ($11-million); and $30-million for similar expenses under the third round. Among these projects, PRDC is the only one down for purely research and development funds.

The authorization hearing brought out JCAE concern over the fact that the electric co-op projects are essentially 100% Federally financed. AEC will build the reactors while the conventional power equipment will be financed by Rural Electrification Administration loans.

Democrats Clinton P. Anderson (N. M.) and Chet Holifield (Calif.) wondered whether AEC would use the co-ops as a precedent for advancing greater financial aid to private industry projects.

Republican Sterling Cole (N. C.) wondered why private industry wasn't being helped to the same extent. He promptly introduced a new bill calling for greater financial aid for nuclear projects on an 80-20% basis, 80% to private industry and 20% to public power groups. This is roughly the division between public and private power generation in the U. S. today.

Second Geneva agenda drafted

A provisional agenda for the second International Conference on the Peaceful Uses of Atomic Energy, to be held Sept. 1–13, 1958, in Geneva, provides for a general session on fusion power possibilities, plus three technical sessions: energy balance in fusion systems; experimental systems; stability and other properties of plasmas. NUCLEONICS will print the entire agenda next month.

U. N. compiles nuclear data

A 251-page compendium of reports on economic applications of atomic energy has been prepared by the U. N. for the use of its Economic and Social Council, meeting this month in Geneva. The report includes replies by Russia as well as Britain, France, Canada and the U. S., to a questionnaire covering nuclear power program activities, prospects and objectives. The Soviet replies cover much the same ground as the Belgrade report (*see p. 20*) but speaks of two, not one, large pressurized water reactor stations, plus a third graphite-moderated, water-cooled reactor station.

Two more U. S. firms choose foreign partners

Continuing a trend (NU, June '57, 23), two more U. S. companies have entered into agreements with foreign firms for joint development of nuclear services. "NDA Europe" has been formed by Nuclear Development Corp. of America together with the Societé Générale des Minerais and the Societé Belge pour l'Industrie Nucléaire (Belgonucléaire), both of Brussels. The new firm will combine U. S. nuclear experience with established European manufacturing facilities. Its office will be in Brussels. Second, H. K. Ferguson Co., Cleveland engineers and builders, teamed up with John Laing & Son Ltd. of London, a large British construction firm with experience on the two Windscale plutonium reactors and South African ore processing plants. The two will offer design and construction services.

German A-law hits snag

By two votes, the Bundestag, lower house of West Germany's parliament, failed to give the required ⅔ majority to a constitutional amendment to permit construction of reactors. This kills the basic atomic law for this year, places the timetable of the entire atomic development program in jeopardy. Chancellor Adenauer's followers, who had promised support, sabotaged the bill by abstaining from voting, because they feared it would prevent West Germany from having nuclear weapons. The government is now trying to shift responsibility for reactor development to the various State governments, to avoid protracted delays.

Russia's A-Power Program Much Like American, Belgrade Report Reveals; First Big Station Like PWR

Russia's present power reactor development program seems to be patterned remarkably closely after that of the U. S. This is the first and most striking impression one gains from a study of the two Russian papers presented at last month's eleventh sectional meeting of the World Power Conference in Belgrade.

For the program is now almost identical, in types of reactors if not their sizes, with AEC's five-year program. It appears to embrace four small reactors—a boiling water, a sodium-graphite, a heavy-water homogeneous using thorium, and a fast plutonium breeder; and two large-scale nuclear stations. Of these one, using pressurized water for both moderation and cooling, follows a design much like a scaled-up Shippingport; the other is water-cooled and graphite-moderated, like Russia's first, 5-Mw prototype, power reactor. This latter type had appeared to be the front-runner for selection as Russia's first large-scale station at the time Dmitri I. Blokhintsev spoke at the Geneva conference in August 1955; as far as one can tell from the Belgrade report, it now appears to be running on a longer time-schedule behind the water-moderated plant, although this is not said explicitly. The large gas-cooled reactor that Vladimir V. Vladimirsky said in New York in October 1955 his country intended to build is conspicuously missing from mention in last month's papers.

If it be true that imitation is the sincerest form of flattery, the U. S. AEC would appear to have reason to feel complimented. On the other hand, whether the Russians have chosen to build only these six first-generator reactors, or whether they merely chose to mention only these at Belgrade, is probably not known this side of the River Bug. If the former, it represents a notable retrenchment over the 2–2.5-million kw program, including four large and ten small experimental reactors, that Igor V. Kurchatov set at the Communist Party Congress in February 1956 (table, NU, Aug. '56, 31). Enigmatic as ever, the Russians—unlike other Belgrade delegates—submitted their papers unsigned—and too late for distribution.

Conclusion of one paper is revealing: "As can be seen from the foregoing, the reactor described is of the ordinary pressurized-water type, like the Shippingport Station reactor, but has a considerably greater capacity.

"It is an interesting fact that the independent development of these reactors in different countries has led to analogous design decisions."

Nuclear Fuel Outlook

The first paper was called "Outlook for Utilization in the USSR of Nuclear Fuel for Power Purposes." After discussing reserves of natural fuel (fossil and hydro), it shows that more than 70% of the total reserves are in Siberia,* and that therefore "it appears most expedient and justifiable" to use nuclear power in the high-cost-power area, i.e. European Russia. It alludes to the desirability of using nuclear stations for space heat and hot-water supply in large supplies, but says "the danger of possible radioactive wastes and the absence of experience in utilizing large atomic installations still bar the use" of reactors for this purpose; "newly-built atomic power stations in the USSR are not being considered for heat output for heating purposes; they will be constructed at a considerable distance from large population centers."

The first large-scale station will have two pressurized water reactors. Conversion factor of ~ 0.8 is expected. "Calculations indicate that plutonium that is extracted from burned-out fuel . . . can fully satisfy the reactor's requirement for enriched material in subsequent charging, whence it follows that to ensure operation of the apparatus U^{235} may be required only for initial charging." This reactor is treated in greater detail in the second paper.

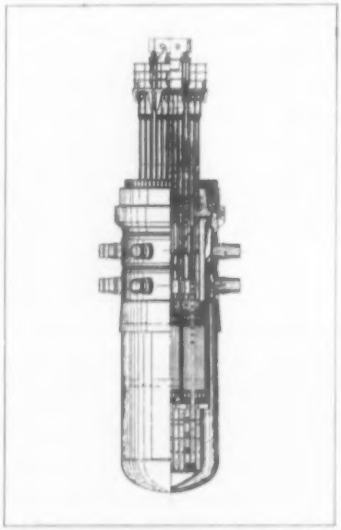
Other reactor types considered promising require further experimental study prior to large-scale use, the report continues. "To obtain this experimental data, it is intended to build four experimental reactor power installations of relatively small capacity, of the order of 5–70 Mw." These are:

1. **A boiling-water reactor** with a thermal capacity of 300 Mw, and 70 Mw (elec), producing saturated steam of 441 psi at the throttle. "There will be natural circulation of the water-steam mixture in the reactor; to check on problems of regulation in the possibility of boosting reactors of this type, there is provided a supplementary steam generator in which steam can be produced on the principle of the 'dual cycle' in an amount up to ⅓ of the steam produced in the reactor." This is the route being taken by General Electric in its 180-Mw boiling reactor for Commonwealth Edison, and by Allis-Chalmers in its 66-Mw unit for the Northern States group (*see p. 57*). With their boiling reactor the Russians propose to obtain data on "the stability of operation of the reactor under conditions of a considerably varying content of steam in the water volume; regulation of the entire unit as a whole; . . . [and] prolonged operation of the turbine on radioactive steam." These are the questions that still confront U. S. boiling reactor designers.

2. **A sodium-cooled, graphite-moderated** reactor will have 150–180 Mw thermal output to produce 50 Mw (elec) using 1,470 psi, 932–950° F steam. As in SRE, there will be an intermediate NaK loop to prevent contact of radioactive primary sodium with water in the power loop. Experimental aims are to determine the neutron physics characteristics of a sodium-graphite reactor and its operating characteristics as a power generator.

3. **A fast breeder** project scaled

* Comparative costs of electric power are given as follows: coal, Moscow region, 8–10 kopecks/kwh; peat, Moscow region, 10–12; brown coal and imported fuel, Urals, 7–8; coal, Siberia, 4–7. In 1955, Blokhintsev's figure for projected cost for power from early 50–100-Mw graphite-water reactor stations was 10–20 kopecks/kwh.



REACTOR VESSEL for Soviet PWR is 39 ft high, has six primary loops. Compare our PWR vessel, NU, Dec. '56, 27

at 200 Mw (heat), 50 Mw (elec), will use the U^{238}–Pu^{239} cycle. As in both EBRs and the Detroit fast breeder, sodium coolant will be used in the primary loop, heated from 554 to 905° F as it goes through the reactor. An intermediate NaK loop will be heated to 842° F and will in turn produce 441 psi, 752° F superheated steam in the steam generator. A "medium-pressure" turbogenerator will serve the installation. "Gasketless hermetic centrifugal pumps will be used for pumping the Na and NaK in the first and intermediate loops." Most important experimental problem here is "the possibility of breeder operation. . . The small dimensions of the core require achieving extremely high heat fluxes at the fuel element surface—76.6–85.2-million Btu/ft²/hr; the problem of reliable cooling must also be solved."

4. A D_2O-moderated homogeneous unit is the "fourth experimental reactor installation destined for construction that may also be used subsequently for power production." Fuel will be "a solution of uranium salts or a suspension of fine powder [slurry] in heavy water." It will be a breeder operating on the Th^{232}–U^{233} cycle; heat output will be 25–35 Mw.

Concludes the report: "Experimental exploitation of the reactors described will make it possible to determine the fundamental operating characteristics of power installations supplied with reactors of these types, their stability and reliability in operation and also the regulating conditions. The possibility of prolonged operation of the plants without fuel recharging, and also problems of chemical processing must also be clarified."

Other highlights of the report:

• "Experience gained from the 5-Mw first atomic power station of the USSR bears out the possibility of operating with a high degree of reliability. In almost three years of operation at this station there has not been any damage from breakdown of fuel elements in the core."

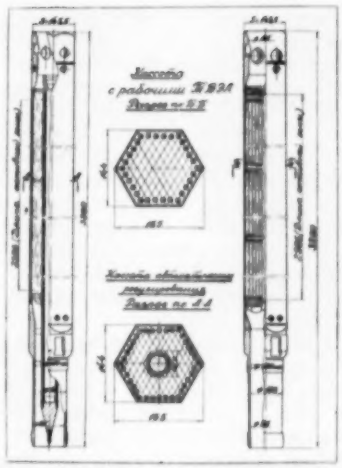
• "Radiation safety of station personnel is achieved by a biological protection arrangement that insures maximum permissible doses of radiation. . . . In particular, the organization of a system of eliminating liquid radioactive wastes from the reactor loop is proposed, in accordance with which system the radioactive products will not go beyond the limits of the station grounds."

• "As concerns breakdown of the cladding of fuel elements from corrosion, data on hand permit considering the creation of corrosion-stable coatings for a determined range of operating temperatures with appropriate choice of coating material."

• "Existing calculated and experimental data permit us to look forward to the possibility of achieving sufficiently deep burnout of the fuel to obtain an economically justifiable cost amount for the fuel component for electric power. . . . Obstructions to the realization of slow fuel burnout can be: losses of fuel reactivity; breakdown of fuel elements as a result of an alteration in the composition of the fuel in proportion of slag [fission product] accumulation, or as the result of the effect of neutron irradiation on the construction materials of the elements; corrosion breakdown of fuel element cladding."

• "Physical calculations for power reactors indicate that it is possible to devise active zones capable of operating for long periods of time without recharging (with a yield from one ton of fuel up to 10,000 Mw-days of power). Such burnout of fuel is higher than that on which the atomic stations being built are based (2,500–3,500 Mwd/ton)."

• "The technical characteristics and, in particular, the power of atomic power stations have been selected so that the cost of the electric power produced in them does not exceed the cost of power at thermal plants."



FUEL ELEMENTS are 10½ ft high, have only one peripheral row of fuel rods; control rods are centered

420-Mw Nuclear Station

The second Russian paper at Belgrade was entitled, "Project for a 420-Mw Atomic Electric Station," and gives a fairly complete technical description of this pressurized-water plant burning slightly-enriched uranium. It is "intended to supply power to a separate district, but will also be connected to the unified power system of the European part of the USSR." The station is expected to go on the line in 1960. The first section of the station will have a total capacity of 420 Mw (elec) in two units, with one 760 Mw (heat), 210-Mw (elec) reactor per unit, and three 70-Mw turbogenerators for each unit. The reactor will feed six circulation loops, each containing a horizontal steam generator, gasketless centrifugal pump, and valves with hydraulic and electric drive that permit disconnection of any loop while in operation. Primary water at 1,470 psi will be heated from 482 to 527° F in the reactor; rated flow through the core is 120,000 gpm; flow velocity in the 21.6-in. pipes is 25 ft/sec; pressure drop in the loop is 69 psi.

Unlike PWR, intake water does not enter at the bottom of the pressure vessel but above the core, and flows down inside the vessel shell cooling the walls before it passes upward through the core. The steam generator produces 470-psi damp saturated steam which is dried in separators. Secondary steam and feedwater lines are "executed in a conventional manner," with two steam generators to each turbine.

The core will be 9.84 ft dia and 8.2 ft high in the form of a removable basket containing 349 hexagonal "casings with fuel elements" of uranium dioxide. The "casings" are hexagonal zirconium tubes 10.5 ft long, 6.5 in. circumscribed dia, 0.079 in. wall thickness; they are arranged in the core in a triangular grating with 5.79 in. spacing. They have cylindrical tips that fit in the basket's bottom thrust plate. For protection from vibration the casings are further fastened to the upper spacing grating which is held by a "clamping cylinder" and rests against the reactor shell lid. Because of the non-uniformity of heat generation within the core, water flow along the casings is redistributed by means of throttle washers mounted in the lower thrust plate. "After actual starting of the reactor and adjusting for non-uniformity of neutron field, the quantity of water flow along the casings can be readjusted."

Inside the hexagonal tubes, fitted

into the triangular grating, are inserted fuel elements of 0.40 in. dia, spaced 0.563 in. apart, and separated longitudinally by several plate gratings.

"There are several ways of loading a core. The first charge should be made of 17 tons of natural uranium dioxide and 23 tons of uranium dioxide enriched to 1.5%. In future, it is planned to use combined charging of natural and considerably higher enriched fuel. Final selection of the most efficient charge will be made only after a certain period of exploitation."

The pressure vessel is a cylinder 12.5 ft dia, 39.4 ft high, with a flat removable lid and elliptical bottom. The shell wall is 3.93 in. thick in its lower and center part and 7.09 in. in the upper, the most stressed, part. In the upper part of the shell are two rows of six nipples each having a 19.7 in. nominal dia, for connecting the six circulation loops, as well as 12 nipples of 3.93 in. for thermocouple lead-outs. Control and safety rod drive gears are [as at Shippingport] mounted on the removable vessel lid. High-strength heat-resistant steel with a yield point of 71,200 psi at 617° F will be used for the reactor vessel, "a factor which provided . . . a two-fold safety factor in the yield point." The interior surface is stainless-lined. Weight without the lid is 170 tons; total dry weight of the reactor is 420 tons. "Protection of the reactor shell from the action of neutrons is accomplished by a steel shield 1.57–3.54 in. thick and 7.88 in. of water."

Automatic Control

Two of the fuel element assemblies have an automatic control rod at the center; control is by replacement of fissionable by an [unspecified] absorbing material. In addition to the two control rods there are six safety rods. Control is automatic: "Basic parameter for control of reactor power is the mean temperature of the reactor coolant, 504° F. When load at the bus bar changes, the governor maintains constant speed by changing the amount of steam admitted to the turbine. A change in steam consumption upsets the equilibrium between steam production and consumption, which results in pressure change at the steam generators, and temperature change in the coolant at the outlet (for coolant temperature increases with a decrease in load and vice versa). Temperature regulators, by changing the reactor power, maintain constant the mean temperature of coolant; the steam pressure in the steam generators is 470 psi abs for normal load, but increases to 735 psi when the load drops to zero. Hourly consumption of coolant for all operating conditions remains the same, and reactor power is changed by its reference input element, and the assigned power level is maintained by an automatic control system with an accuracy of ±1%."

Core unloading is done by a 125-ton capacity electric bridge crane under a protective layer of water up to 15.2 ft, permitting personnel to remain in the reactor control hall. Either individual casings or the whole core as a unit may be unloaded; it is estimated that to remove each casing separately would take 4 days, to unload the core as a unit 2 days. All material removed will be held 180 days underwater in a holding tank.

Each steam generator—a tubular heat exchanger—is calculated to produce 230 tons/hr of dry saturated steam at 470 psi and a feedwater temperature of 378° F. Primary water flows through the tubes and secondary water is on the shell side. Heating surface is 13,890 ft².

The six gasketless, lead-proof main coolant pumps are in parallel, one in each primary loop; they are vertical, single-stage centrifugal assemblies in which the hydraulic part and the electric drive are constructed in a single unit, and the working volume is hermetically sealed from the atmosphere. Each pump has an output of 23,100 gpm and develops a pressure of 71.2 psi. Cooling of the bearings is done by the operating fluid, fed to the bearings through a special cooler by means of a vane mounted on the upper end of the pump rotor. The bearings are unloaded of radial and axial stresses; they are instrumented for temperature and for wear.

Circulating water is drawn off at a rate of 106 gpm for cleaning in a multistage evaporator. Condensate goes back to the reactor circuit and the residue to a radioactive dump.

Gross energy efficiency of the station is 27.5%; electric energy consumed for its own needs is 7.45%.

PRDC Hearings Off Until August

AEC last month summoned its own witnesses to testify before its examiner, Jay A. Kyle, on the fast breeder construction permit issued the Power Reactor Development Co. Previously, the three unions that had petitioned for suspension of the permit on the ground the reactor would not be safe at the Lagoona Beach, Mich., site, had completed their presentation.

The hearing will resume in August to hear the last of AEC's witnesses, Manson Benedict of MIT. PRDC will then have a chance for rebuttal, after which the hearing record will go to AEC for consideration and a final decision.

U. S. Ratifies IAEA Statute After 10 Other Nations

The U. S. became the eleventh country to ratify the statute of the International Atomic Energy Agency on June 18, when the Senate approved the charter, 67–19—a far bigger margin than the two-thirds required. Four days earlier the Senate Foreign Relations Committee had unanimously approved the statute, with one qualification proposed by Republican Senators William F. Knowland (Calif.) and Bourke B. Hickenlooper (Iowa). However this was not a formal reservation, but merely expressed the understanding of the Senate in ratifying the statute that any proposed amendment to the statute would be brought before the Senate, and that the U. S. would not remain a member of IAEA if the latter adopted an amendment to the statute opposed by the Senate. During two days of floor debate the Senate turned down 55–31 a reservation that would have required Congressional approval for each U. S. offer of nuclear material to the Agency. The final vote saw 35 Democrats and 32 Republicans arrayed against 9 Democrats and 10 Republicans.

Afghanistan, Austria, Byelorussia, Guatemala, Norway, Pakistan, Rumania, Switzerland, the Union of South Africa and the USSR had ratified before the U. S.; since then Czechoslovakia has also ratified. Eighteen nations including three of the atomic Big Five must ratify for the Agency to come into being; its first (and founding) General Conference is set for Oct. 1 in Vienna.

Washington Report

During the first two weeks in November the Atomic Energy Commission hopes to complete the transfer of its 1,490 employees to its new headquarters building at Germantown, Md. Located in farm country, 25 miles from the District of Columbia, the new building is scheduled for completion Nov. 2. The move was set at a time when dispersal of vital agencies outside the D. C. target area was required by a White House order, since withdrawn.

The move will mark the first time since AEC has become a major Federal agency that the staff will be housed in one office building. For the past few years the Commission has been split between 1901 Constitution Ave. where the Commissioners, division of public information and some other divisions are located, and 1717 H St. where the rest of Commission, including the division of reactor development, is located. Prior to occupancy of 1717 H St., much of AEC's staff was scattered in World War II temporaries.

In preparation for the move, AEC has had a special staff working for the past two years on the various problems involved.

A major concern has been housing in an area inhabited largely by grazing cattle. Many employees will have to commute from Washington, or move into nearer Maryland suburbs such as Bethesda and Rockville.

Another concern will be maintaining the staff at full strength. AEC expects to lose fully half its stenographic help. Major reason for this is the fact that commuting costs will equal a salary grade.

Some technical help will be lost but the Commission is coy as to the precise figures. Actually, AEC employees have not yet been asked for a firm answer on whether or not they will make the move. This won't come until August.

To gain some idea of where it stood, the Commission hired the Boston consulting firm of Harbridge House, Inc., to make a survey of employee intentions. AEC is reported to have been shocked by its revelations, more pessimistic than AEC expected. Lack of housing was the leading reservation in the minds of employees about making the move, the survey showed.

AEC figures that recruitment, training, processing and clearance of an employee costs $1,000. On the basis of this figure it sought an allowance of up to $600 per employee for moving expenses over and above the normal moving costs which will be reimbursed. The figure was to cover closing fees in house purchases, lease severance fees in the case of renters, auto registration fees, and similar expenses involved in moving. The Bureau of the Budget turned down the request.

AEC'S NEW HOME is shaping up today like this (compare with architect's sketch NU, Jan. '56, 11). Germantown headquarters is 27 mi by car from downtown Washington

The new headquarters has been designed to hold 1,600 employees. Already AEC has outgrown this figure and a request is now pending in Congress for authorization to add another wing to hold 200.

Once the move has been made, AEC will maintain in Washington a document room, a hearing room, and a few offices for the use of Commissioners and other officers coming into the District on business.

People doing business with AEC are going to find the new location inconvenient, at least at the start.

Transport. The Government will supply bus service to AEC, but for Government employees only, according to present plans. For businessmen the best bets will be their own or rented cars or taxis. However, AEC now says it is exploring the possibility of providing transportation for its contractors' representatives when they are calling on official business. Greyhound runs 8–9 buses a day but the closest stopping point now is a mile from AEC. The Baltimore and Ohio railroad passes through Germantown itself, also a mile from AEC. But B&O runs a commuter service, three trains in to Washington in the morning, two trains out in the evening. This schedule would have to be reversed to meet AEC needs, but the road wants a guarantee of enough business before it puts on new trains.

Shelter. There is one fairly large motel, the Washington, near the new building and others farther away. One would-be builder of a motel opposite the new building, designed for businessmen calling on AEC, has encountered zoning trouble: Montgomery County has zoned much of the area for industrial, rather than commercial or residential, use.

Food. Eating will be another problem. AEC will have a 350-seat cafeteria and a 150-seat dining room. The Washington Motel has a 97-seat dining room. But for fancier eating, diners must find transportation to one of three good country restaurants within a 15-mile radius, or return to the District.

A-Power Plant Builders Report New Progress

Clark Goodman of AEC and six power project officers briefed the American Nuclear Society meeting in Pittsburgh last month. Highlights:

Goodman—Components for LAPRE-2 were largely on hand when LAPRE-1 failed; it's planned to complete and test the former. . . . EBR-1 is being rebuilt, not only to take the Mark-3 core (NU, Feb. '57, R10), but also to permit primary cooling to be changed at will from series to parallel. . . . LAMPRE, the molten plutonium fueled power test, may use a tantalum container for the Pu-Fe fuel alloy. . . . "The general shift to oxide away from metal fuel elements represents a compromise taking poorer nuclear physics for improved radiation damage properties and better compatibility between fuel element and coolant."

Harrer on **EBWR**—Operating experience has been satisfactory (*see p. 61*). Only mishap: a feedwater pump failed when the thrust bearing disintegrated.

Peabody on **Dresden**—The detailed engineering design is 50% complete (cf NU, Jan. '57, R8) and will be finished by end of 1958; half the hardware (on a dollar basis) has been ordered, the rest will be ordered by end of 1957. . . . The fuel element design has been changed; instead of two types of element—fuel and fuel-&-poison—there will be only one standard fuel element, and control will be by cruciform (EBWR-type) poison elements. This is intended to give better distribution of moderator in the core, reduce fuel enrichment requirements, reduce hot-spot danger, provide more adequate control, and simplify design. There are now 80 control rods; each fuel element has 36 fuel rods in 6×6 array. . . . The external water tower for emergency cooling has been abandoned; instead the emergency cooling system will be placed in the sphere top, as in EBWR. . . . A ⅛-scale model has been built to study flow characteristics.

Ward on **Indian Point**—Foundations will be poured starting September or October. . . . A new fuel element has been designed (photo NU, April '57, 20). Present schedule calls for non-nuclear testing to start in March 1960, critical testing in August, and full power operations—originally set for May 1960, will now begin in January 1961. . . . Chicago Bridge & Iron will build the sphere. . . . $10-million will have been committed for equipment, $3-million for construction—for the nuclear portions only—by year's end.

Amorosi on **Fermi (PRDC) Fast Breeder**—Reactor vessel is complete except for welds connecting major sub-assemblies. Optical methods are being used for aligning major vessel parts for joining, as an almost unprecedented ⅛-in. tolerance on the center-line is specified. The vessel will be completed and subjected to pressure tests in a few months; then the internal shield, hold-down plate and rotary shield-plug will be installed and tested for alignment, and the unit shipped before year's end. Plans are still to go critical in December 1959 "± several months."

Stoker on **Yankee**—Heavy construction will begin in 1958; the site has now been cleared, and meteorological and hydrological tests and drilling are under way. This plant lags behind the others by 6–12 months.

Fax on **Pennsylvania Advanced Reactor**—Goal is still to be in service in 1962. Corrosion is proving on the basis of long-run loop tests to be less of a problem than had been feared. So far no problems have been encountered that the group does not feel it can solve.

GE is in Fusion; UK Briefs Industry

General Electric has established "a substantial research program" to study the possibilities of fusion power, vice-president and research director Guy Suits revealed, a brief month after General Atomic division of General Dynamics made the first announcement of private-industry-financed work in the field. "Our work on fusion," Suits said of GE, "has been going on for over a year and is expanding." Heading the project is Henry Hurwitz, Jr., formerly of the Knolls Atomic Power Laboratory's reactor programs; it is being carried out at the GE Research Laboratory in Schenectady. The project is not yet fully staffed.

British Active

Many British firms not previously concerned with nuclear power were among those invited to a three-day conference at Harwell to discuss practical applications of fusion power and to be briefed on latest British and U. S. developments in its industrial uses; 25 AEC delegates were observers at the secret talks. The briefing was considered revolutionary in view of the large number of firms invited* and the amount of information believed disclosed.

T. E. Allibone, director of the research labs of AEI (which holds a British government contract for fusion power research), told the meeting that success in harnessing the thermonuclear reaction might come within 10 years, and rated this as "possible"; success by century's end he considered "probable."

* They included: AEI-John Thompson Nuclear Energy Co.; British Electrical Transformer Co.; British Thompson Houston; British Insulated Callenders Cables; Central Electricity Authority; Chloride Batteries; Crompton Parkinson; Dubilier Condenser Co.; English Electric; Electrical Research Ass'n.; Electrical Musical Industries Ltd.; Ferranti; General Electric Co.; Hawker Siddeley; Head Wrightson; International Combustion; Imperial Chemical Industries; Magnetic & Electrical Alloys; Nuclear Applications Ltd.; Nuclear Power Plant Co.; C. A. Parsons Ltd.; Plessey Ltd.; Reyrolle; Richardsons Westgarth; Standard Telephones & Cables; Simon-Carves; Telcon-Magnetic Cores; Telegraph Construction & Maintenance; Vickers Nuclear Engineering Ltd.; Whessoe.

First West Coast A-Sub

Sargo, Navy's fifth nuclear submarine and first of three building at Mare Island Navy Yard near San Francisco, takes shape. September is tentatively set for launching of Skate-class boat. Stern is at bottom, with inner pressure-hull plates not yet fixed to ribs

Reactor News

AEC STRETCHES OUT FLUID FUEL OFFER

AEC has extended the minimum completion date for third-round plants using fluid fuel reactors from June 30, 1962, to "at least" June 30, 1963. The decision was based on the prolonged delay in the startup of Homogeneous Reactor Experiment-2 at Oak Ridge National Laboratory, and the consequent slowing of progress since AEC issued the third invitation under its Power Demonstration Program last January (NU, Jan. '57, R1; Feb., R6). The principal private project for a homogeneous power reactor is the Pennsylvania Advanced Reactor of Pennsylvania Power & Light Co. and Westinghouse. "We doubt whether we want to qualify under the extension," PP&L officials told NUCLEONICS. The one-year extension doesn't apply to them, they said, for in no case could they determine technical feasibility of their reactor until mid-1958. Furthermore, they maintain that AEC's new cutoff date is too restrictive and that research-development cannot be legislated by timetables. The other private homogeneous project, that of Wolverine Electric Co. and Foster Wheeler (NU, March '56, 21), is in the second round, thus not affected.

DRESDEN UNDER WAY—OFFICIALLY

With excavation completed and below-grade concrete pouring well advanced, it was "start of major construction" rather than ground-breaking that was observed at the site of Commonwealth Edison's 180-Mw Dresden nuclear power station. 400 visitors joined the 600 workmen for ceremonies that included erection of the first of 20 steel columns 2 ft dia and 55 ft high to support the 190-ft steel containment sphere.

GE OFFERS JAPAN A DRESDEN COPY

General Electric has submitted proposals to Japan's AEC and utilities there to build a 186-Mw nuclear power station in Japan. It would feature a dual-cycle boiling water reactor similar to the 180-Mw Dresden station GE is building for Commonwealth Edison of Chicago. Much of the equipment and accessories for the plant would be produced in Japan.

RELOADING EASES HOT FUEL TESTING

Hot fuel samples taken from MTR loops may be reinserted with the use of a new "hot reload system" devised by a Knolls Atomic Power Lab group working at the Materials Testing Reactor in Idaho. The new equipment permits a single fuel sample to be used through an entire series of experiments, makes it possible for samples to be removed from and replaced in the test loop as often as desired. Tests may be interrupted for higher-priority work and continued later without impairment. Initial cost of the new equipment was $20,000, said to have been "more than saved" in the first experiment conducted; savings of $100,000/yr in time and material economies are forecast.

AMF SELLS POOLS IN ITALY AND PORTUGAL

SORIN, the joint Fiat–Montecatini nuclear development company (NU, Sept. '56, R6), has bought from AMF Atomics a 1-Mw pool for industrial research, isotope production and personnel training. It will be the first privately-owned and -operated research reactor on the continent. Provision will be made to increase power level to 5 Mw. . . . AMF Atomics sold another 1-Mw pool to Portugal for its new nuclear research center near Lisbon.

EXPENSIVE ALPR BID ACCEPTED

AEC has awarded a contract for construction of the non-nuclear part of the 200-kw Argonne Low Power Reactor to Fegles Construction Co. of Minneapolis, low bidder at $752,000, even though the bid was almost double AEC's preliminary estimate of $400,000. Fegles was one of seven bidders. The work, including power plant, supporting buildings and equipment, is to take 300 days.

HARDEMAN LOW BIDDER ON SPERT-2

Paul Hardeman Inc. of Los Angeles, with a $1.2-million low bid, won an AEC contract to build the SPERT-2 facility at the Idaho reactor testing station (NU, June '57, 26). Six other firms bid. Hardeman is also building SPERT-3.

ALASKAN APPR SEEN SOON

A 2-Mw package power plant—APPR-1a, a duplicate of the Ft. Belvoir APPR—will be installed at an Army post in Alaska "soon," says Maj. Gen. E. C. Itschner, chief of the Army Corps of Engineers. Alco, builder of APPR, has been designing the new unit (NU, April '57, 19), expected to operate at a cost of 1¢/kwh and still save money in Alaska by eliminating transport of 16-million lb/yr of oil.

KIDDE TO SURVEY SITES FOR PAR

Walter Kidde Nuclear Laboratories has been engaged by the Pennsylvania Advanced Reactor group to do site surveys and preliminary safety analysis; Kidde will also continue work on ventilation started last fall. Westinghouse and Pennsylvania Power & Light are developing PAR, a 150-Mw aqueous homogeneous plant; Union Carbide is working on chemical reprocessing of the mixed thorium-uranium slurry.

WORK STARTS AT WALTZ MILL

Westinghouse broke ground July 8 at Waltz Mill, Pa., for WTR (NU, June '57, 26), first privately-financed, industry-owned materials testing reactor.

NEW CRITICAL FACILITY IN IDAHO

A low-power reactor called ETRC—Engineering Test Reactor Critical Facility—was put in operation at AEC's reactor testing station. Function of the 50-kw unit, whose core is identical with that of ETR, is to test nuclear behavior of the larger machine, leaving it free to run at full power.

DANISH FUEL CONTRACT TO B&W

Babcock & Wilcox's Lynchburg fuel-element plant is making the 20%-enriched assemblies for Denmark's tank research reactor; 33 fuel and 12 fuel-control elements are to be delivered by Sept. 1. The reactor is to begin operation in October. B&W is also making 38 elements for a similar research reactor for the Livermore lab. Both reactors are being built by Foster Wheeler.

SEAWOLF PILING UP MILES

The Navy's second nuclear submarine returned from a post-shakedown Caribbean cruise with 13,800 miles recorded in her log, more than 9,000 of them submerged.

Report from Spain:

Sense of Urgency Grips Madrid on Nuclear Power; Conventional Sources to be Fully Exploited in 10 Years

MADRID

In the past year a sense of urgency has taken hold in Spain with regard to atomic energy development. The reason is that in ten years' time the country's conventional sources of power will have been tapped to the maximum limit of economic possibilities. The development of hydroelectric power will have reached its maximum capacity. Coal is already scarce and has to be imported. Yet Spain's population is increasing at a rate of two million every five years, and power consumption is going up at a faster pace than in any other European country (in the last 10 years at an average rate of 8.6%/yr). Like Britain, Sweden, and some other European countries, Spain must have nuclear power as a matter of economic life or death.

Experts calculate that by 1967 power from conventional sources will amount to 9-million kw installed but that by 1972 2–5-million kw additional will be needed if the country's needs are to be met. Ten years from now Spain must either import increasing quantities of fuel or draw on atomic energy if the country is to be saved from economic collapse. Consequently serious study is being made of nuclear power possibilities.

This year the budget of the Junta de Energia Nuclear, Spain's advisory body on atomic development, has been tripled: it now stands at 300 million pesetas ($6.54-million).

So far these things are being done:

• Spain is exploring its uranium resources. Deposits have been discovered in the provinces of Cordoba, Jaén, Caceres, Badajoz and Salamanca. First estimates set the deposits at 400,000 tons of secondary ores yielding 1–6 Kg/ton, following exploration by means of pit-heads and drilling.

• A concentration plant for treating the ore is being built at Andujar and will go into operation this fall, processing 30,000–40,000 tons/yr.

• A heavy-water production plant has been set up in Huesca province.

• A 3-Mw pool-type reactor is to come into operation in 1958, for training personnel, at the Moncloa research center NW of Madrid.

• Besides the Junta de Energia Nuclear, other bodies are directly interested in atomic energy development. The government's Instituto Nacional de Industrias will have a lot to say regarding the eventual purchase of atomic power plants manufactured abroad. A non-governmental, private group, consisting of Iberduero, Electra de Viesgo, and the Banco de Viscaya, has formed a company called Centrales Nucleares del Norte. Another grouping of private firms, calling itself Tecnatom, has been formed (NU, May '57, 27) by Spanish industrial concerns looking ahead to the supplying of atomic equipment. They, with the Urquijo Bank behind them, want to promote domestic building of atomic plants.

The Spanish government has final say on what Spain's atomic energy

1. *Salamanca*
2. *Caceres*
3. *Badajoz*
4. *Cordoba*
5. *Jaén*
6. *Huesca*

program is to be. Such a program, formulated by the Junta, is presently under consideration. It is known to recommend the setting up by 1961 of a big material testing reactor or, alternatively, the installation by 1963 of a 20-Mw heavy water reactor. Big business (Centrales Nucleares del Norte) is pressing for the purchase abroad, next year or in 1959, of a large reactor for industrial purposes.

The Junta feels that nationalization of the production of fuel elements for the reactors is imperative. It considers that government supervision can best favor the exploitation of the country's natural uranium resources. The idea is that the more Spain draws on domestic fuel for its reactors, the more spare cash there will be for purchasing needed atomic equipment manufactured abroad. It doesn't want foreign exchange—always short in Spain—to be used for importing enriched fuel when the country's own deposits may be made to yield what is needed. For this reason there is intense interest in exploration of the possibilities of uranium ore found in Spain. It is felt that research on fuel should be developed and experience gained as much as possible now pending further atomic development in the United States, Britain and France—from which Spain could later conclude what types of reactors best meet its needs.

Personnel training has high priority in the atomic development program. Since its creation in 1951, the Junta de Energia Nuclear has been training graduate science students from the universities and the schools of engineering, sending a selected number abroad for further instruction. Of 130 student-scientists, 50 have supplemented their studies with sojourns abroad ranging from six months to three years. Specialists were at first sent to Italy, then to Switzerland, the United States, Great Britain, Germany, Norway and France. The lifting of secrecy on atomic development that had obtained in most countries until 1954 has eased the problem of turning out competent atomic scientists in Spain, but the Junta feels more will be needed than are available.

AEC Licensing News

Construction permits issued: General Electric, for GETR, a 30-Mw pressurized water test reactor; and for a critical experiment facility on Spanish research reactor, both at Vallecitos, Calif., 6/14/57

General Dynamics, for an experimental nuclear facility and a series of initial uranium foil experiments, at San Diego, 6/18/57

Curtiss Wright, for a 1-Mw pool-type research reactor at Quehanna, Pa., 6/20/57

Export licenses issued: Babcock & Wilcox, to export pool-type research reactor to Society for Utilization of Nuclear Engineering in Shipbuilding and Navigation, Hamburg, 6/7/57

Intercontinental Chemical Corp., to export a 50-Kw L-54 Atomics International solution-type research reactor to Farbwerke Hoechst AG, Frankfurt, 6/11/57

Export applications received: ACF Industries, to export a 30-Mw tank-type reactor to Swedish AEC, 6/18/57

World News

Chinon Plant Moving Ahead

Excavation has been completed at EDF-1, France's first all-power nuclear plant at Avoine near Chinon (NU, Aug. '56, R11; Sept., R6; Dec., R9). A 187-ft dia *concrete* sphere on the bank of the Loire will contain the steel-and-concrete-shielded reactor, fuel handling and control mechanisms, four heat exchangers, turbo-blowers and auxiliary equipment; outside in a separate building will be the turbogenerators. The 60-Mw graphite-moderated CO_2-cooled unit is slated to enter service in 1959.

Green Light for Third CEA A-Station

Britain's Ministry of Power has given formal consent for construction of the Central Electricity Authority's third (after Bradwell and Berkeley) nuclear power station at Hinkley Point, Somerset (NU, June '57, 27). Biggest yet planned in Britain, it is to produce 500 Mw (elec) from two 250-Mw improved Calder-type reactors, will cost $168–196-million. The English Electric–Babcock & Wilcox–Taylor Woodrow consortium will submit a bid this week to CEA; if it's accepted, work will start in September for completion by late '59 or early '60.

French Test Reactor Started at Saclay

EL-3, France's $10-million high-flux materials testing reactor (NU, Dec. '56, R10) was started up July 4.

Merchant A-Ships Pushed Abroad

The Italian Line announced at the keel-laying of the 31,500-ton *Leonardo da Vinci*, replacement for the *Andrea Doria*, that the 60,000-hp vessel's design will permit future conversion to nuclear propulsion. This is the second such design, following the French Line's new *France* (NU, Sept. '56, R11) . . . In Sweden, Uddevallavarvet, a shipyard at Uddevalla, said that the third of three 65,000-ton tankers it will build for Ships, Inc., a Cities Service Oil Co. affiliate, will be powered by a U. S.-built reactor. However, E. G. Maddock, Cities Service vice president, said the atomic plan was still tentative. The tankers are each to have 22,000-hp turbines and a speed of 16½ knots.

Notes from Britain

Sale of at least one Calder-type to Italy has been "practically settled" according to *The Times* of London. It quoted British Board of Trade head David Eccles in Rome after his talks with Enrico Mattei, head of the Italian state oil monopoly, ENI. Mattei is said to have recommended to another Italian state enterprise considering purchase of a U. S. reactor that it first study Calder Hall. . . . Chairman Koichi Uda of Japan's AEC said at the end of a fact-finding mission to Britain that the U. K.'s chances of selling a Calder reactor to Japan are much better. . . . The Ministry of Supply is considering use of a Saunders-Roe "Princess" seaplane as a test-bed for its atomic plane program. The three prototypes built have been written off as commercial craft for lack of adequate engines, are mothballed at Southampton. The use of one for ANP studies is felt to be attractive, as the U. K. has been concentrating on seaplane design in its nuclear propulsion program. A Bristol Proteus-755 turboprop might be the powerplant. Rolls-Royce declined comment on reports it had asked the Ministry for use of one flying boat for this purpose.

Priority for Indian U-Plant

Top priority has been assigned construction of a uranium metal plant to make fuel elements for the Canada-India reactor (NU, June '56, 23; Feb. '57, R11) and for the zero-energy research reactor (NU, May '57, 27), both now building at Trombay. CIR is to operate by year's end, the critical facility in 1958. Officials have confirmed that recently-found U and Th deposits 10 ft from the surface at Ranchi in Bihar province are 50% larger than the Travancore-Cochin deposits and double India's reserves of radioactive minerals.

Geneva Reactor Again Critical

The U. S.-built Geneva exhibit reactor has at last gone critical again in its new Würenlingen home near Zürich (NU, March '57, R8). It is now at work as a research tool, at a power level of 1 Mw as against the demonstration power levels of 10–100 kw at Geneva.

Denmark Buys Third Reactor

A British Pluto-type (D_2O-moderated and -cooled) materials testing reactor has been ordered by Denmark from Head Wrightson Ltd., London, for $4.2-million for completion by late 1959. The U. K. will supply enriched reactor for the unit, third reactor for Denmark's Risø nuclear center. Two Plutos are nearing completion in Britain at Harwell and Dounreay.

First Baghdad Isotope Class

The new Baghdad Nuclear Training Center (NU, April '56, 23; May '57, 27) has enrolled its first class of 20 graduate students, five each from the mideastern members of the Baghdad Pact: Turkey, Iraq, Iran, Pakistan. The present short intensive course in principles and handling of radioisotopes is patterned on the Harwell course. Applied research is undertaken by the 8-man permanent staff, headed by W. J. Whitehouse of AEA; the center's future activities will be extended to basic research after a research reactor has been built. The economic committee of the Baghdad Pact has allocated $70,000/yr to the Center for operating expenses, to be met by the five Pact members (Britain is the fifth). The U. K. is also paying all capital expenses.

Safety Branch Set Up in AEA

A safety branch to handle all hazards evaluation has been set up within the U. K. Atomic Energy Authority. Composed of a safety executive committee and a health advisory committee, the new group will scrutinize safety factors in nuclear development for AEA, advise other users of AEA services, and advise government departments on safety legislation.

East Germany Plans A-Ships, 20 Plants

About 20 atomic power plants will be built in East Germany by 1970, the E. German Office for Nuclear Research says. Russia had promised help building a first 100-Mw unit (NU, Aug. '56, R11; Nov., R11). And the Warnow Shipyard at Warnemünde on the Baltic is said (by Radio East Berlin) to be "continuing preparatory work to make construction of the first nuclear-powered vessel possible this year."

Czechs Mark Progress

Major construction has been completed at the Czech nuclear center near Prague and the buildings are to be completed late this summer, ready for installation of the Soviet 2-Mw reactor (NU, April '56, 19).

News in Brief

ANP Test Facility Contract Let; Another Postponed

A $6.04-million flight engine test facility at AEC's Idaho reactor testing station will be built by Howard S. Wright Construction Co. of Seattle. It will permit testing of nuclear engines in conjunction with airframes, typical crew compartments, and aircraft control systems (NU, May '57, 22). The work is to be completed in two years. The winning offer, lowest of seven bids, represents the largest lump-sum contract ever awarded by AEC's Idaho Operations Office. . . . Bid opening date on the Shield Test Pool Facility, another Idaho ANP project, was "postponed for an indefinite period to allow changes in the invitation."

Army Seeks Nuclear Manpower

Nuclear physicists and "nuclear effects engineers" are two of 21 types of scientific specialists being offered Regular Army commissions. The military is seeking up to 200 outstanding men in critical fields. Apply to the Adjutant General, Army Dept., Washington 25, D. C.

Construction Permits for 17 AGN-201s

AEC has issued construction permits for 17 Aerojet-General Nucleonics low-power research reactors, 16 of them standard 100-milliwatt units, and one with extra shielding and instrumentation for 5 watts.

Southwestern Utilities Organize

Southwest Atomic Energy Associates has been formed by 13 utilities in Arkansas, Kansas, Louisiana, Mississippi, Missouri and Oklahoma, spearheaded by Middle South Utilities Inc., whose reactor program (NU, Jan. '57, R1) the group takes over. A four-year, $5-million research program is planned, to develop a new, advanced reactor design that the group could then build and operate competitively in 200–400-Mw sizes.

ANS Elects

Leland D. Haworth, director of Brookhaven National Laboratory, is the new president of the American Nuclear Society. Titus LeClair of Commonwealth Edison is vice-president, and Montgomery Schultz of Westinghouse treasurer.

ANS Pittsburgh Unit Assumes State Role

The Pittsburgh section of ANS has set up a committee on professional licensing to which Pennsylvania has given responsibility for preparing and grading exam papers for the State professional examination for nuclear engineers.

New Team: Walter Zinn and AMF

A training reactor for use by universities and industry will be designed by Walter H. Zinn's General Nuclear Engineering Corp. and produced by AMF Atomics. The "Educator," an improved version of the Argonaut, is rated at 10-kw, uses water-graphite moderator and is characterized by minimum excess reactivity.

Crane Builds Valve-Test Loop

A $150,000 stainless-steel test loop for checking reactor valves at temperature and pressure has been put in operation by Crane Co. at its Chicago works. It can test valves from 4 to 16 in., is operated by a 10-hp canned rotor pump.

Clevite Joins Case Group

Clevite Corp. became the seventh member of the Case Industrial Nuclear Center study group which is planning a private research reactor at Cleveland (NU, Feb. '57, R12; April, 24).

Another Expansion at NDA

A 63-acre tract at Greenburgh, N. Y., will serve—subject to a zoning change—as a Nuclear Development Co. of America research and development center and as its new headquarters—third major expansion program in 1½ years (NU, Feb. '56, 16; April, 24; Feb. '57, 131). The present White Plains headquarters building will become a manufacturing center.

GSA Contract Awards

Universal Transistor Products Corp. has received a $281,800 General Services Administration contract for 50,000 dosimeter pens and 12,000 dosimeter chargers. Victoreen got a $1-million GSA order for portable fall-out-monitoring survey instruments.

Mitchell Resigns as AEC Counsel

William Mitchell, general counsel for AEC since March 1953, has resigned to return to private life. His deputy, Edward Diamond, was named acting general counsel as of June 15.

Pace Sanguine on Fusion

"We may get some really amazing results" from the fusion power program at General Dynamics' General Atomic division (NU, June '57, 17), said GD president Frank Pace Jr. The division is doing "extremely attractive" fusion research, he said, adding, "If General Dynamics is to know greatness as a corporation, it will come through General Atomic division." The nuclear bomber project at Convair division is advancing and will materialize "at a time no man can predict," he said.

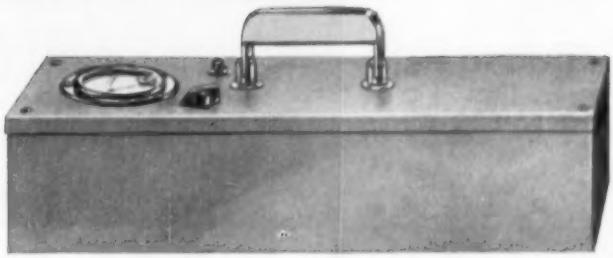
New York Expands Radiation Study

A committee of experts has been appointed by the New York State Industrial Commission to look into the effects of radiation in the nuclear industry; amendments in the state's protection standards are anticipated. Fields being explored include: (1) modification of present limits on radiation exposure; (2) labeling of low radioactivity materials such as electronic tubes; (3) registration of low-hazard installations; and (4) adequacy of radiation safety officers's training and of hazard surveys.

Godiva-2 Operating

Following the destruction of Godiva, Los Alamos' bare U^{235} critical assembly, last February (NU, April '57, 104), an improved successor has been placed in operation. Temporarily known as Godiva-2, the new device was designed specifically as a controlled prompt-critical irradiation assembly (unlike Godiva-1, built to study a critical assembly and the effects thereon of foreign materials). Instead of being spherical, Godiva-2 looks like a beehive—cylindrical with a shallow-domed top. The critical mass is in two main sections resembling a piston entering a cylinder; three control rods also enter the assembly from beneath—two screw-driven, the third fired by a pneumatic cylinder. A 5/16 in. dia horizontal transfer tube permits firing samples pneumatically through the active region. Godiva-2 is a more self-contained unit, and structurally more rugged, than its predecessor.

New



RCL's Fast-Slow Neutron Survey Meter

Greater Gamma Discrimination, Transistorized and Etched Circuitry actually years ahead of its time.

Greater gamma discrimination capabilities, lighter weight, printed circuitry throughout, log scale, reduced power requirements are only a few of the features that make the RCL the neutron survey meter of tomorrow.

Greater Gamma Discrimination: You receive one hundred times the gamma discrimination ability with the RCL Fast-Slow. The RCL discriminates against gamma radiation up to 100 r/hr; others cannot discriminate above 1 r/hr.

Completely Transistorized: Oscillator H. V. supply, completely transistorized, is lighter, more efficient than a vibrator, needs less current. Reduced power consumption, plus the mercury cell power supply affords much longer battery life. Needs no warm-up time.

Lighter Weight: Easier to handle. New RCL model is transistorized, smaller gross size and weight, uses less power. Weighs less than ten pounds.

Logarithmic Rate Meter: Log read out allows you to read the entire range of the instrument on a single scale.

SPECIFICATIONS:

Slow Neutron Detector: Enriched BF_3 detector counts neutrons below 0.1 MEV.

Fast Neutron Detector: Methane-Argon filled, polyethelene lined detector counts neutrons with energies between 0.1 and 15 MEV.

Power, High Voltage Supply: Two 22½ volt, 1000 ma-hr Mallory mercury cells and one 1½ volt Mallory mercury cell, transistorized oscillator circuit developing 1500 volts.

Count Rate Meter Circuit: Transistorized three stage amplifier and trigger pair, followed by tank circuit and log scale electrometer tube.

Radiation Counter Laboratories, Inc.

NUCLEONIC PARK, SKOKIE, ILLINOIS

Radiation Counter Laboratories, Inc., Dept. 177
Nucleonic Park, Skokie, Illinois

Gentlemen: Please send me additional specifications, price quotations, and delivery information on RCL's Fast-Slow Neutron Survey Meter

Name _____

Title _____

Firm _____

Address _____

City _____ State _____

BACKGROUND LESS THAN 1 CPM

with the

Tracerlab

low-background beta counting system

- **Plateau slope less than 1% per 100 volts**
- **Ultimate sensitivity of 0.05 cpm**
- **Window thickness less than 1mg/cm²**

Tracerlab's new Low-Background Beta Counting System offers the ultimate in sensitivity for solid samples of beta-active materials. It is the first *complete* beta counting system ever offered commercially with a background of less than one count per minute.

This remarkably low background allows the assay of samples with very low specific activity. For instance, the CE-14 Low-Background Beta Counting System offers a sensitivity to carbon-14, a factor of 10 greater than a windowless flow counter. The sensitivity ratio is even greater for isotopes with higher energy beta radiations.

The plateau slope of less than 1% per 100 volts means unusually stable operation for periods of months or years, with excellent reproducibility of results. The central beta counters are designed for continuous gas flow to insure maximum long-term reproducibility.

The CE-14 Low-Background Beta Counting System is complete with two central flow counters and mercury isolation shield, inside a dust-tight steel cover which also houses the anticoincidence umbrella. The massive shield, gas flow system and special three-channel anticoincidence scaler are included as an integral part of the complete system.

A detailed description of this Low-Background Beta Counting System is available. Write for bulletin CE-14.

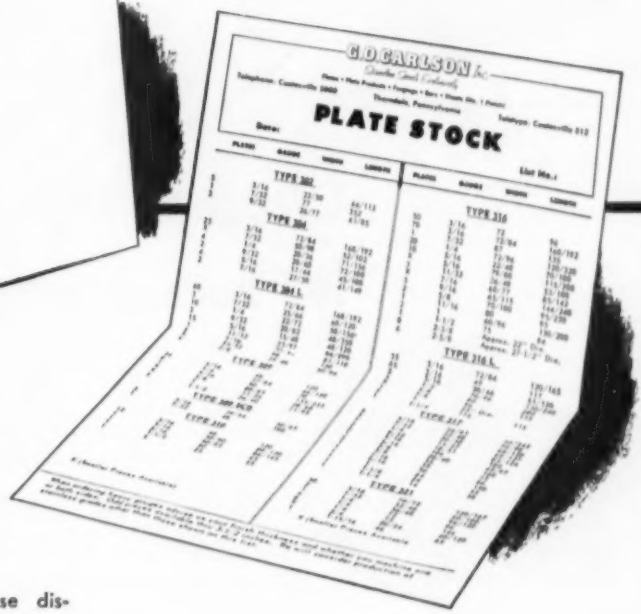
Tracerlab

1601 Trapelo Rd., Waltham, Mass.
2030 Wright Ave., Richmond, Calif.

Offices in principal cities throughout the world

Keep up to date...

on Stainless Steel Plates and Heads



Carlson's Weekly Stock Lists tell you what you want to know:

- the Type, Gauge, Width and Length of stainless steel plates in stock.
- the Type, Gauge and Size of stainless steel heads in stock.
- the sales representatives and warehouse distributors in this country and Canada who are ready to serve you.

YOU can save time by checking these weekly stock lists. Here is an up-to-the-minute report on our large, diversified stock of stainless steel plates and heads that have been produced especially for chemical industry applications.

Carlson plates in Types 304-L, 316-L and 317-L are more and more in demand. Substantial stocks of these extra-low-carbon grades, along with other chromium-nickel Types 302, 304, 309, 309-S, 310, 316, 317, 321, 347 and 348 are available. Chromium grades 405, 410, 430 and 502-½% Mo are always in stock. Two precipitation-hardening grades, Types 17-4 PH* and 17-7 PH*—new plate grades that combine ease of fabrication, hardenability, high strength and corrosion resistance—are now in production and limited stocks are carried. To complete the story, stainless steel heads in Types 304, 304-L, 316 and 316-L are also stocked and can be shipped in a few days.

Make Carlson your *one-stop* source for that complete bill of material—stainless steel plates, heads, rings, circles, flanges, forgings, bars and sheets (No. 1 Finish).

When you need stainless plate . . .

Carlson gives you what you want when you want it!

*Trade Mark of ARMCO STEEL CORPORATION

G.O.CARLSON Inc.

Stainless Steels Exclusively

THORNDALE · PENNSYLVANIA

District Sales Offices in Principal Cities

G. O. CARLSON, INC.
138 Marshalton Road
Thorndale, Pennsylvania

Write for your copies of Carlson's Weekly Stock Lists . . . use this convenient coupon.

Name: .....

Company: .....

Address: .....

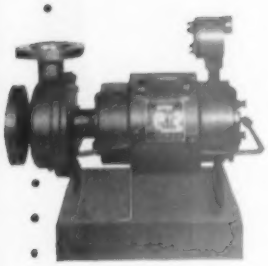
City: ..... State: .....

Series C *Chempump*

Series DE *Chempump*

Series E *Chempump*

Chempump...
for zero leakage canned pumping!



Series T *Chempump*

Series S *Chempump*

Here's a line of canned pumps that have proved themselves in even the most critical nuclear applications . . . handling "hot" and corrosive fluids without leakage or contamination and with a minimum of maintenance.

The original canned pump, *Chempump* combines both pump and motor into a single leakproof unit. No seals, no stuffing boxes. Bearings are constantly lubricated by the pumped fluid itself.

Chempump is widely used today in reactor research, test loop systems and fuel preparation and processing . . . in isotope production . . . in water treatment and waste disposal. Whatever the nature of the fluid—volatile, toxic, corrosive, explosive, radioactive, sensitive—*Chempump* has long experience in handling it without difficulty.

The *Chempumps* shown here are part of the standard line. They're available in a wide choice of materials, including Monel, Hastelloy B and titanium. Capacities range to 250 gpm; heads to 195 feet. They handle fluids at temperatures to 1000° F. and pressures to 5000 psi. Other models can be custom-made to your specifications.

For complete details, write to Chempump Corporation, 1300 East Mermaid Lane, Philadelphia 18, Pa. Engineering representatives in over 30 principal cities in the United States and Canada.

Chempump . . . first in the field . . . process proved

Loading Face of BNL Research Reactor at
Brookhaven National Laboratory, Upton, N. Y.

New Brookhaven fuel element gives improved performance

Scientists and engineers of the Brookhaven National Laboratory have conceived a reactor fuel element of advanced design that promises to greatly improve the usefulness of the BNL Reactor.

The new design differs markedly from the one used originally when the Brookhaven reactor — the first large-scale research reactor in the United States — was put into operation in 1950.

The original fuel elements were natural uranium slugs, 4 in. by 1.1 in. in diameter, canned in finned aluminum tubes.

The improved two-foot element, shown above, is an assembly of three fuel plates which contain highly enriched (93%) uranium-aluminum alloy clad in aluminum. It is expected to afford these important advantages:

1. Higher neutron flux—an increase from the present 5×10^{12} up to 3×10^{13}.
2. Lower total reactor heat output — a reduction from 24 to 20 megawatts.
3. Less cooling air required—due to improved aerodynamic design of the enriched elements.
4. Higher fuel burn-up of contained U^{235}-up to 40% burn-up with enriched elements compared with 10% obtained with present natural uranium fuel.
5. Reduced reactor inventory of U^{235}-from 385 Kg contained in present fuel to 55 Kg in enriched elements.

With more than eight years' pioneering experience in the fabrication and development of all types of fuel elements, Sylvania-Corning Nuclear Corp. was chosen to supply several hundred test elements of the new design. These were installed in the central "hot spot" of the reactor for proving out.

Results have proven satisfactory and Brookhaven has decided to go ahead with the complete replacement program based on the new design. Sylvania-Corning Nuclear Corp. will supply the 5000 fuel elements needed.

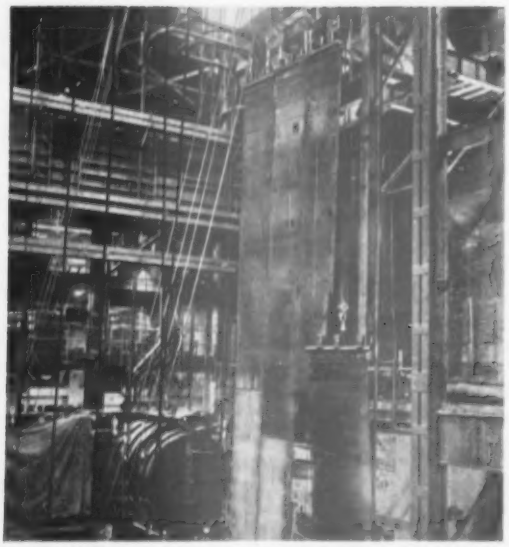
Whether your own reactor is in actual operation, or merely in the planning stage, our scientific and engineering staff is ready to assist you, too, in achieving improved fuel performance. For your files, write for our booklet on Nuclear Fuel Elements.

SYLVANIA-CORNING NUCLEAR CORPORATION, Bayside, N. Y.

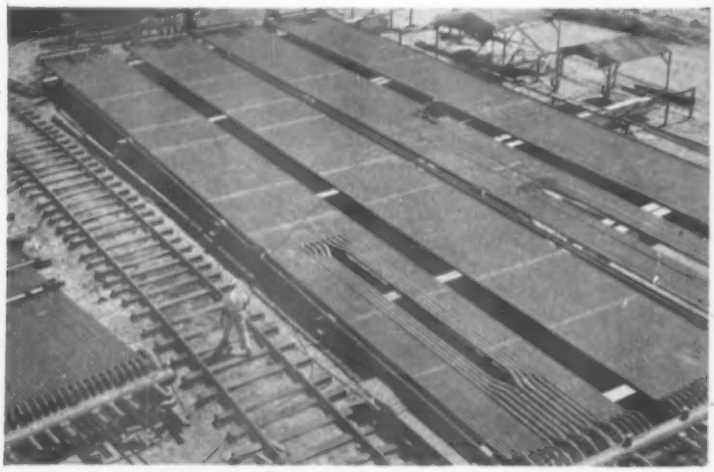
B&W AND ATOMIC ENERGY

How to Put

TONS OF CONCRETE, poured into this web of wire, will form walls of B&W-engineered swimming pool type research reactor.



SUPERCRITICAL pressure steam generator, the world's first, saw B&W engineers solve new design, fabrication, and erection problems.



ERECTION means smooth flow of components into place. Here side wall of high pressure, high temperature boiler is prepared for hoisting.

HERE ARE THE REASONS WHY B&W ENGINEERS KNOW...

a Nuclear Reactor Together

Putting a nuclear reactor together is an exacting engineering task. Research and power reactors are designed and fabricated to meet specific needs. But design and fabrication alone will not assure required operating characteristics. It's the job of the erection engineer to precisely assemble components into a working system.

SAFETY AND ECONOMY in assembling and testing research reactors and nuclear steam generating plants require skill in established construction methods. But with this skill, there must be combined advanced scientific and nuclear engineering techniques. B&W erection engineers have already acquired an extensive backlog of atomic energy experience, and are keeping up with the fast moving developments in the peaceful applications of this new source of energy.

LONG EXPERIENCE with high pressure vessels for example, has been applied by B&W to atomic energy's similar problems. It has been fortified by a continuing, independent program of nuclear research to make the Babcock & Wilcox position unique in design, fabrication, and erection for the atomic energy field.

STEP BY STEP, B&W engineers have followed progress in design and fabrication with improvements in erection methods. New techniques and tools have been developed and tested. Alloy welding, radiography, magnafluxing, and stress relieving processes have been adapted to the particular needs of erection.

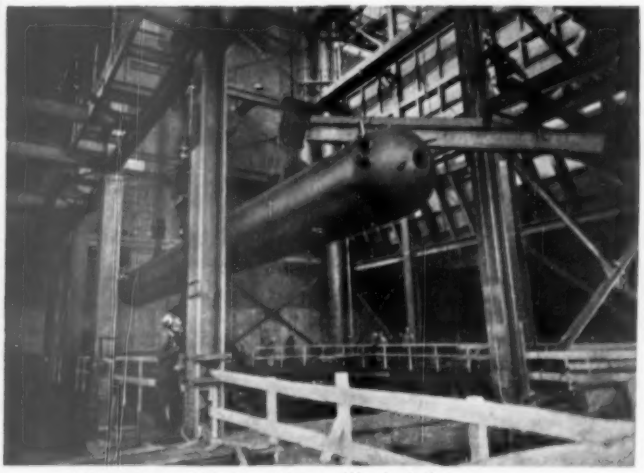
HIGHLY SKILLED EXPERTS with special training supervise erection. Precision is their watchword and the newest techniques are at their finger-tips. Behind them stand nearly 100 years of B&W experience and the entire chain of specialized B&W engineering skills.

COORDINATION of all B&W departments assures a continuity of responsibility in one company from planning to starting up operations. Write for Bulletin AED-6, "B&W Builds a Research Reactor." The Babcock & Wilcox Company, Atomic Energy Division, 161 East 42nd Street, New York 17, N. Y.

BABCOCK & WILCOX

B&W

ATOMIC ENERGY DIVISION



KNOTTY erection problems, like hoisting a many-ton drum into position often over 100 feet above ground level, are taken in stride by specially trained engineers.

B&W'S STORE of high pressure welding experience is added to newest welding metallurgy refinements required for atomic energy projects.

AE-37-A

ANNOUNCING

Nuclear-Chicago's new radiochemical program

Offering "Research Quality" radiochemicals and a new concept of customer service.

161 Carbon-14 Compounds in license exempt 50 μc. packages

156 Carbon-14 package sizes carried in stock

Guaranteed shipment within 24 hours of order by PREPAID air express

42 *New* Carbon-14 Compounds

Including labelled steroids at high specific activity, low cost

47 *New* Sulfur-35 Compounds

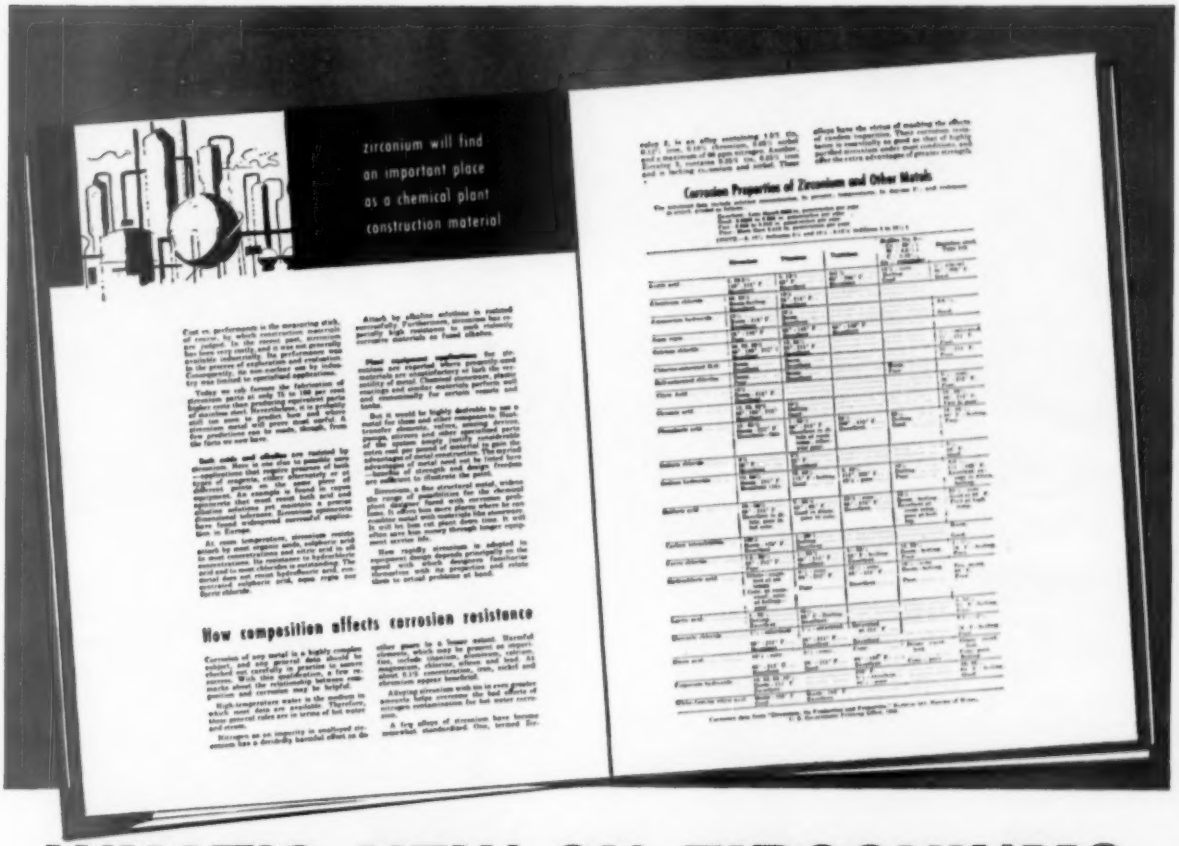
35 *New* Phosphorus-32 Compounds

Write for complete Radiochemical Price Schedule C listing *guaranteed* delivery and quantity discounts of each compound. Available also on request, new 64 page Catalog Q, covering Nuclear-Chicago's newly-designed line of precision radiation measuring instruments.

Fine Instruments - Research Quality Radiochemicals

nuclear-chicago CORPORATION

235 WEST ERIE STREET • CHICAGO 10, ILLINOIS


Zirconium will find an important place as a chemical plant construction material
How composition affects corrosion resistance
Corrosion Properties of Zirconium and Other Metals

WHAT'S NEW ON ZIRCONIUM?

This U.S.I. booklet gives you information you can use . . . Send for a copy!

Today, with zirconium production trending sharply upward, and price downward, interest in this new and unique metal is growing rapidly.

To answer your questions about zirconium and its relative, hafnium, U.S.I. has prepared an informative new booklet — "ZIRCONIUM and HAFNIUM." The booklet gives the important facts on these newly available metals . . . lists important mechanical and physical properties of both . . . describes briefly the new semi-continuous sodium reduction process for production of zirconium and hafnium.

You'll find the outstanding corrosion properties of zirconium compared with other important metals... phase diagrams of twenty binary alloy systems . . . descriptions of several fabrication techniques.

You're sure to find "ZIRCONIUM and HAFNIUM" valuable in discussions and as a preliminary reference. For your copy, forward the coupon today . . . or just send your name on your company's letterhead.

U.S.I. INDUSTRIAL CHEMICALS CO.
Division of National Distillers and Chemical Corp.
99 Park Ave., New York 16, N. Y.
Branches in principal cities

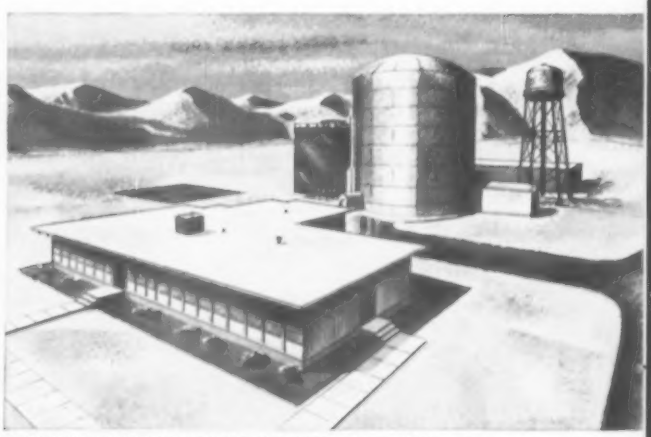
Please send me a copy of "ZIRCONIUM and HAFNIUM"

Name _____
Title _____
Company _____
Street _____
City _____ Zone _____ State _____

DR. R. D. BENNETT, Vallecitos Atomic Laboratory Manager (left), and **E. P. LEE,** Manager of Plant Operation, view Lab-

General Electric Vallecitos Atomic Laboratory

PURPOSE OF EXPERIMENTS to be conducted in Developmental Boiling Water Reactor is to develop economic nuclear power. Facility will furnish steam to 5000-kw turbine-generator, owned and operated by Pacific Gas & Electric Company.



GENERAL ELECTRIC TEST REACTOR, planned for completion in 1958, is a new concept in reactor design developed by General Electric. This 30,000-kw test reactor combines features of tank and pool reactor types.

oratory's facilities: Radioactive Materials Laboratory (right), Experimental Physics Laboratory (center), Developmental Boiling Water Reactor (rear). New General Electric Test Reactor (not shown) will be completed in 1958.

will help speed economic nuclear power

LABORATORY IS NATION'S LARGEST PRIVATE NUCLEAR RESEARCH FACILITY

Progress in private industry's determination to reduce the cost of nuclear power was made May 22 when the new General Electric Vallecitos Atomic Laboratory at Pleasanton, Calif. was dedicated.

At Vallecitos, advanced research and development facilities will be utilized to help accelerate the practical application of atomic energy.

The Radioactive Materials Laboratory will be used to study irradiation effects on reactor fuels, components and structural materials. These studies will lead to improved reactor technology.

The Experimental Physics Laboratory contains a critical assembly which will be used to study reactor core configurations and fuel loadings. A Nuclear Test Reactor will also be used for general physics experiments and calibration.

The Developmental Boiling-Water Reactor, to be completed later this year, will be used to develop important research data on power reactor systems.

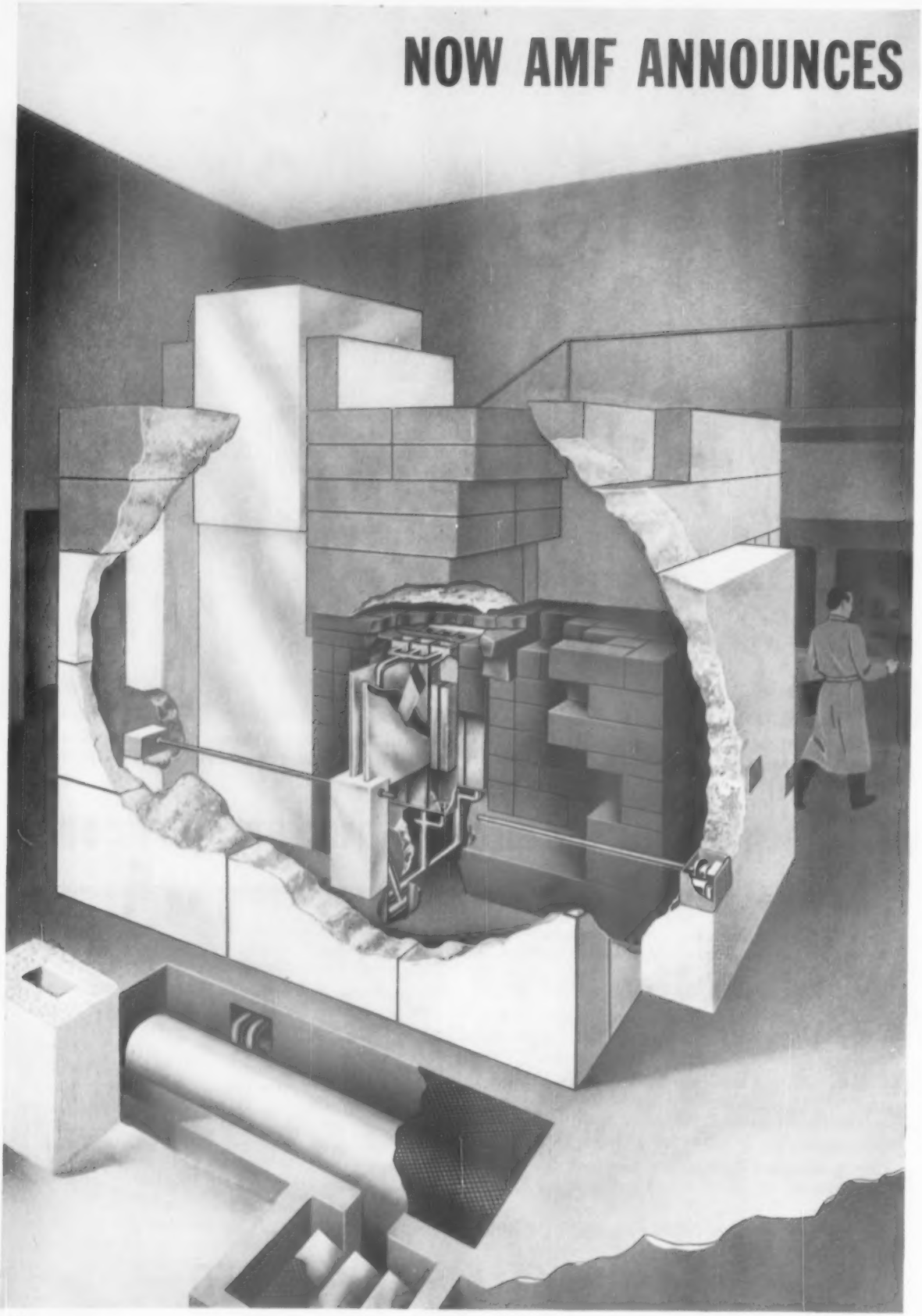
A General Electric Test Reactor (GETR) will be added next year to test materials and components for the Company's nuclear projects.

The multi-million dollar Vallecitos Atomic Laboratory represents another significant step taken by private industry in developing practical applications of atomic energy. Atomic Power Equipment Dept., General Electric Co., San Jose, California.

197-5

Progress Is Our Most Important Product

GENERAL ELECTRIC


NOW AMF ANNOUNCES

a new training reactor—the AMF-GNE Educator

AMF ATOMICS, the world's leader in research reactor design and construction, has joined forces with Dr. Walter H. Zinn and his General Nuclear Engineering Corporation to provide a new and improved version of the Argonaut-type training reactor.

EDUCATOR TRAINING REACTOR

TYPE
Thermal heterogeneous

POWER
Operating power 10 KW thermal, continuous

FLUX
At center 10^{11} neutrons/sq cm/sec

FUEL
Uranium-aluminum alloy arranged in 24 bundles and containing approximately 3.8 kg of U-235 in 20% enriched fuel

MODERATOR
Graphite and light water

CORE
5 ft. x 5 ft. x 4 ft. rectangular prism of graphite containing 6 light-water-filled aluminum fuel boxes

COOLANT
Light water pumped into fuel boxes with gravity feed to heat exchanger and storage tank

CONTROL
4 swinging-arm type blades
Light water moderator quick dump

SHIELDING
5 ft. concrete block

This new AMF-GNE Training Reactor offers universities and educational systems everywhere a low-cost facility that is both unusually safe and highly flexible in application. Experience-dictated modifications and improvements made on the Argonaut-type design by General Nuclear Engineering Corporation, coupled with the reactor engineering and construction experience of AMF, has made the Educator the most advanced of all reactors for university training.

Essentially a water-and graphite-moderated, graphite-reflected reactor, the Educator has been designed for graduate and undergraduate studies and industrial training. It offers a comprehensive facility for training in reactor physics and engineering, as well as in nuclear physics, radiochemistry, radiobiology, and related fields.

Safety—Since the reactor is designed to operate at the low power level of 10 kw, there is a minimum of excess reactivity, and the amount of contained fission products is small. There is no credible way in which the fission products can escape the fuel elements. The reactor is, therefore, perfectly suited for a university campus installation.

Since the core is based upon the design developed in the Borax experiments, the reactor is inherently safe. Proper control of the fuel loading of the reactor is all that is necessary to insure that no accidental mismanagement will result in the release of fission products from the fuel plates.

Low Cost—The simplicity and small size of the Educator permits installation in an existing building, without requiring any other construction. Generally speaking, campus locations should be possible, and the reactor itself is highly adaptable to a variety of installation requirements.

Versatility—The AMF-GNE Educator is designed for continuous operation at 10 kw, giving a thermal neutron flux of 10^{11} neutrons per sq. cm/sec. Horizontal and vertical thimbles, a thermal column, and a large water tank providing flexible irradiation space are features of the installation. Possible experiments include control rod calibration, neutron optics, neutron flux determination, chemical analysis by activation, irradiation of biological materials, and a wide range of other reactor and irradiation studies.

Assistance Program—In addition to the actual manufacture and installation of the reactor, AMF and GNE can assist in any or all phases of your nuclear energy training program, including:

1. Site investigation
2. Preparation of hazards summary report
3. Application for license, grants, fuel processing and fabrication
4. Reactor start-up, calibration, and test
5. Operator training at an existing facility
6. Suggested reactor experiments
7. Safety and health physics program

If you are now, or plan soon to be, engaged in nuclear physics and engineering training, be sure to discuss your plans with AMF ATOMICS. You'll find AMF's unequalled reactor experience the perfect partner to your program. For more information on any phase of AMF's complete nuclear reactor facilities, from design through operation and training, write us today.

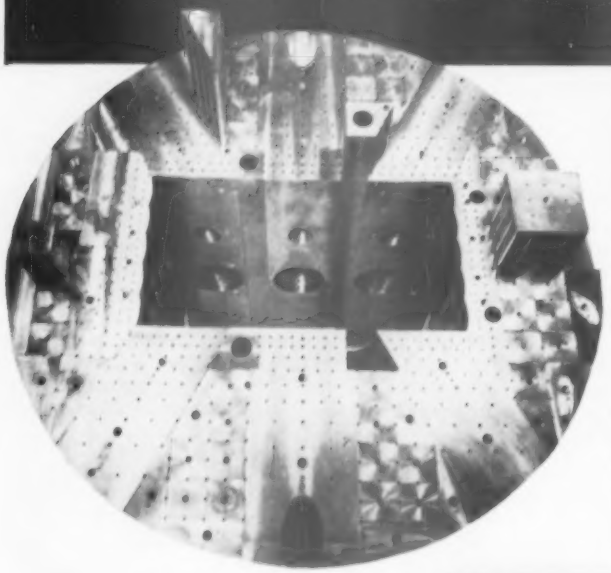
AMF ATOMICS

AMF ATOMICS
A Division of AMERICAN MACHINE & FOUNDRY COMPANY
AMF Building • 261 Madison Ave. • New York 16, N. Y.

- *Power and Research Reactors*
- *Radiation Process Equipment*
- *Reactor Control Systems*
- *Radio-active Material Handling Equipment*

Versatile BERYLLIUM

..unique properties valuable for a wide range of applications.



6000 pounds of QMV Brand Beryllium Metal machined to close tolerance for reflector area of the Materials Testing Reactor, Arco, Idaho.

LIGHT WEIGHT—1.84 gr/cc

HIGH STRENGTH—80,000 psi @ 70° F.
(EXTRUDED) —45,000 psi @ 900° F.

HIGH MODULUS—44.3 x 10^6 psi.

HIGH MELTING POINT—2340° F.

CORROSION RESISTANCE—to air, water and liquid metals

GOOD MACHINABILITY

GOOD THERMAL PROPERTIES

LOW NEUTRON-CAPTURE X-SECTION

HIGH NEUTRON-SCATTER X-SECTION

0.6 GRAMS of high purity QMV Brand Beryllium, per piece, machined to tolerance of ±.0002" per in. These pieces are used in missile control systems.

Pure Beryllium Metal has a wide range of uses in Nuclear Energy applications. Investigations now in progress show potential uses as structural members for airframe applications and airborne guidance devices.

Brush Beryllium

PURE BERYLLIUM METAL
BERYLLIUM-COPPER
BERYLLIUM MASTER ALLOYS
BERYLLIUM OXIDE

PURE BERYLLIUM METAL
Be QMV BRAND

THE BRUSH BERYLLIUM COMPANY, 4301 PERKINS AVE., CLEVELAND 3, OHIO

9836-D operating in the linear servo channel of the Penn State Reactor (PSR).

L&N 18-RANGE MICRO-MICROAMMETER

Follows Flux levels from start-up to scram

This micro-microammeter has been developed for phototube and ionization chamber measurements by L&N engineers who are intimately associated with the measurement and control needs of the nuclear technologist. With its 18-position range selector switch (maximum switching capacity for a unit of this type) the instrument makes an ideal power-level indicator in the linear servo channel of a research or power reactor. The operator simply changes range as power level increases.

Readings are highly accurate because they're stabilized for zero and gain by a combination of a-c amplification and null-balance feedback circuitry. The a-c amplification stabilizes zero; feedback stabilizes gain. Trimmer controls are unnecessary.

For installation flexibility the micro-microammeter is supplied in two models. The 9836-D operates manually from the reactor control panel; 9836-E includes a bi-directional Ledex mechanism actuated from a range selection switch at a remote location.

Accuracy of amplifier—For 1 megohm or greater source resistance, ±0.5% of the reading ±2 x 10^{-11} amp. For source resistance 0.1 to 1 megohm, ±0.8% of the reading ±2 x 10^{-11} amp.

Sensitivity of meter—±0.5% of scale span.

Response to within 1% balance—On most sensitive setting, less than 1.5 seconds at 1 megohm minimum source resistance. On all other ranges, less than 1.8 seconds at 1 megohm minimum source resistance. On all ranges, less than 2 seconds at 0.5 to 1 megohm.

Get complete details from your L&N Field Office or write for Data Sheet E-03(1) to Leeds & Northrup Co., 4936 Stenton Ave., Phila. 44, Pa.

LEEDS NORTHRUP
Instruments Automatic Controls • Furnaces

There is a Purolator filter for every Nuclear application

The filtration requirements of the nuclear field cannot be filled by a limited range of stock filters. To meet these requirements, this is what Purolator has to offer . . .

Purolator can completely design and construct all types of special filters, separators, strainers and pressure vessels for: gaseous diffusion, filtration or separation of gases and liquids; removal of solids from gases or liquids or any combinations of these . . . whether the materials requiring filtration are alkaline, corrosive, or at very high or low temperatures.

The widest possible range of operating conditions can be handled by Purolator filters. Specifically:

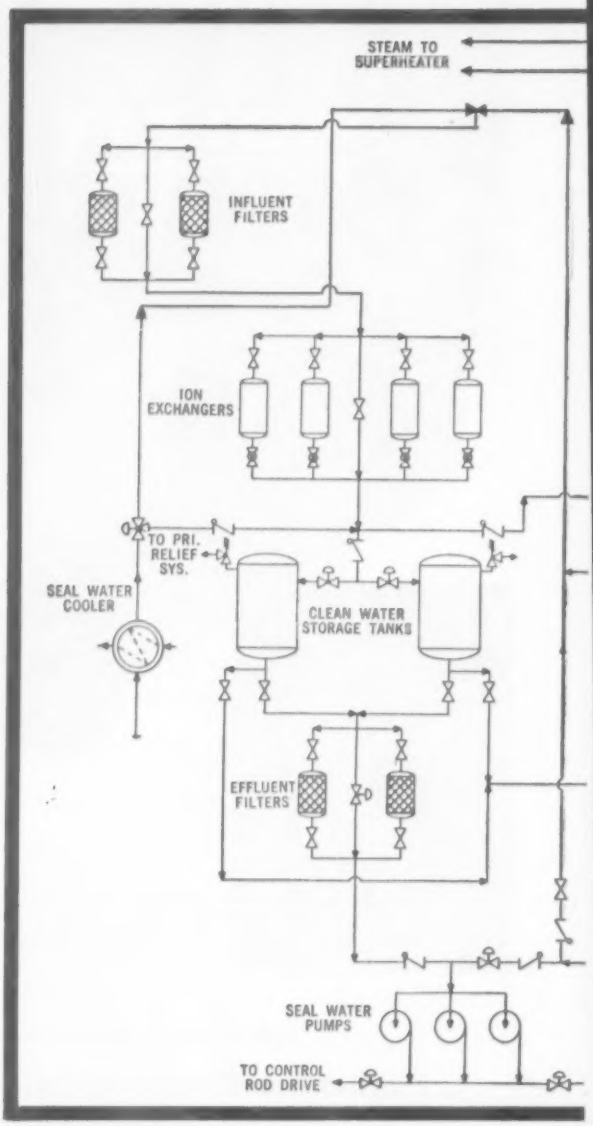
TEMPERATURE: from –420° to 1200° F.

PRESSURE: from a nearly perfect vacuum to 6000 p.s.i.

RATE OF FLOW: from drop by drop to thousands of gpm.

DEGREES OF FILTRATION: from submicronic to 700 microns in various media.

This unequalled range of operating conditions is possible because Purolator can construct the filter and elements of fibers, fabrics, plastics, stainless steel, monel, nickel, inconel, silver, gold, platinum, palladium and any other metal or alloy as required. Purolator filter elements have these exclusive characteristics.



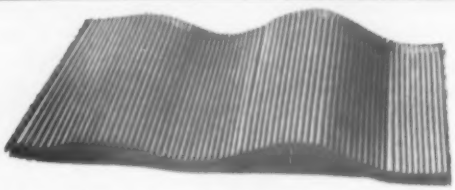
GREAT SURFACE AREA per unit of volumetric space.

CONTROLLED PORE SIZE: from submicronic to 700 microns dependent upon media.

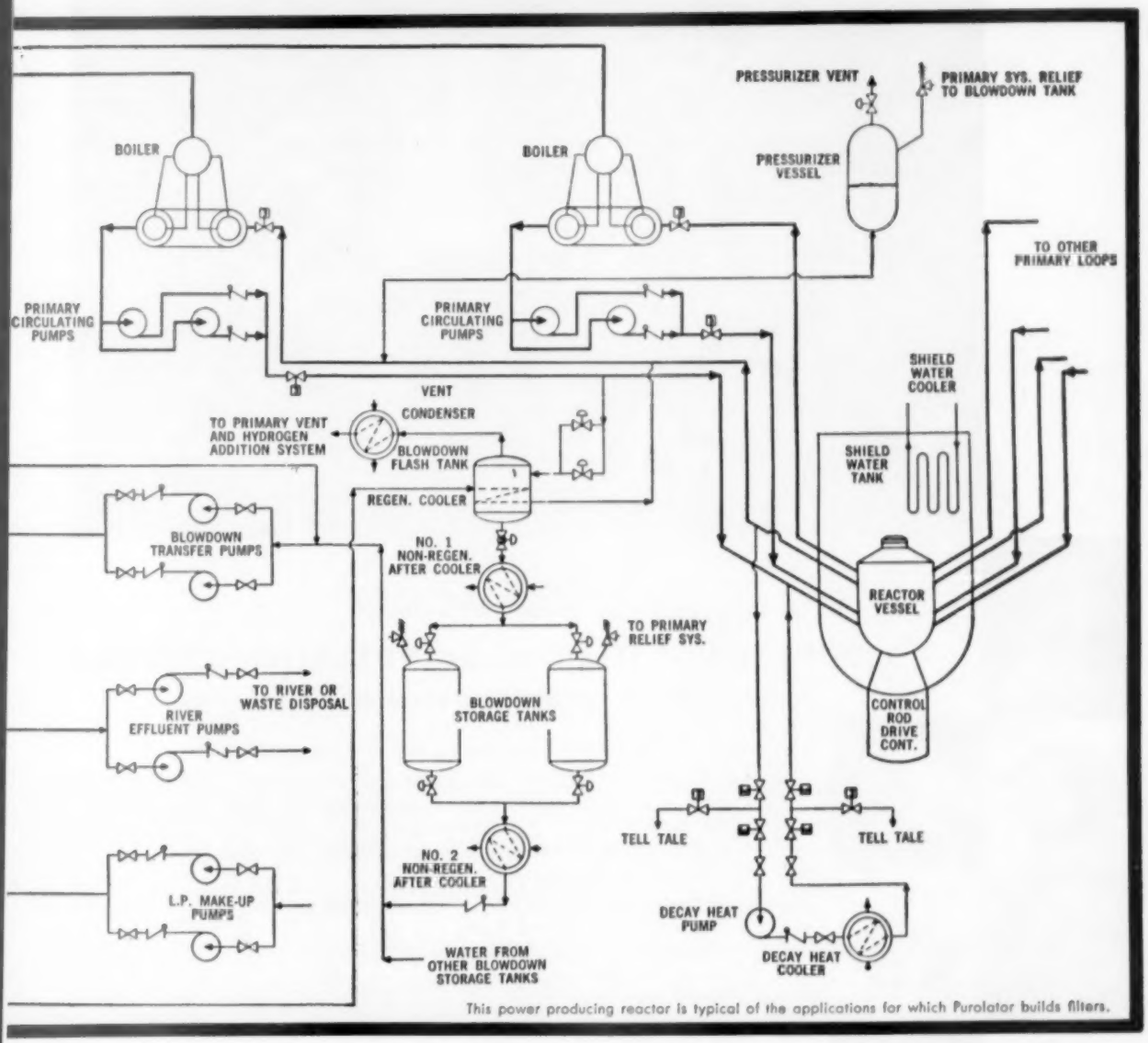
HIGH PERMEABILITY

HIGH DEGREE OF DUCTILITY

THIN WALL: providing easier cleaning and decreased differential pressures.



This convoluted section makes it possible to squeeze 6 square feet of effective filtration area into a filter element 3½" in diameter by 18" in length.



This power producing reactor is typical of the applications for which Purolator builds filters.

FUSED SEAMS: Purolator uses an exclusive (patent applied for) process of fusing component parts with the same materials used as filter media. This eliminates faults inherent in welding (carbide precipitation, internal stresses, etc.).

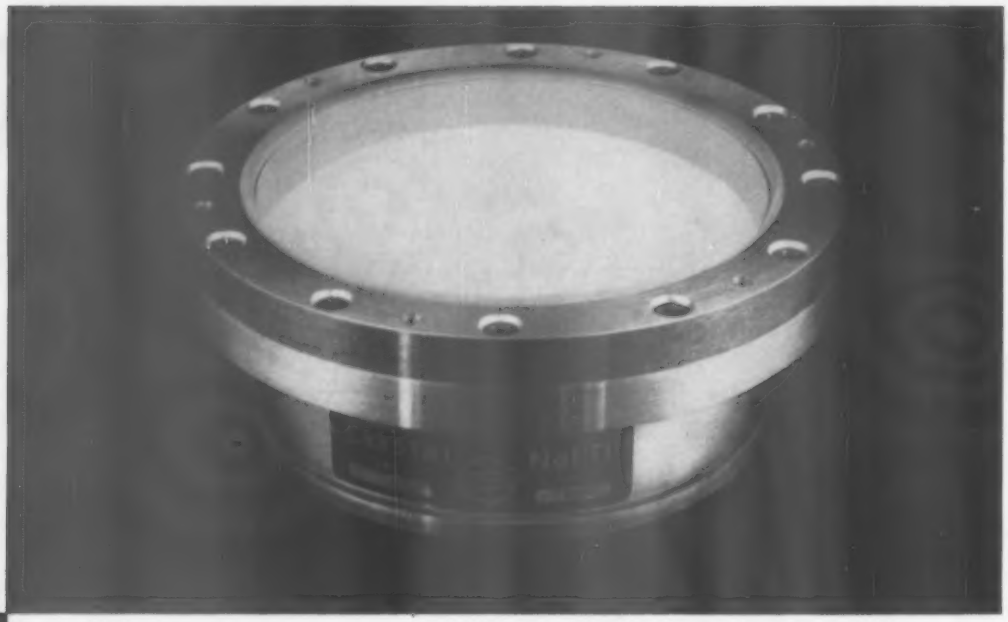
It's obvious that these developments by Purolator are of unequalled value to the nuclear field. Just as important is Purolator's knowledge of how to use them to solve your problems. Purolator's leadership in the development of filtration systems for industry provides a background of engineering and manufacturing capabilities that is unequalled. The statement, "Filtration for Every Known Fluid," is based on solid fact. Evaluate Purolator filtration. Ask Purolator to solve your toughest filtration problem.

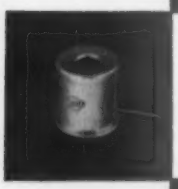
Filtration For Every Known Fluid

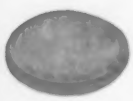
PUROLATOR

PRODUCTS, INC.

RAHWAY, NEW JERSEY AND TORONTO, ONTARIO, CANADA







Harshaw

SODIUM IODIDE (Thallium) SCINTILLATION CRYSTALS

for Gamma Radiation Detection Instruments

"Harshaw Quality". . . inherent in each Harshaw-made crystal

The high purity, clarity, and proper activation of Harshaw Crystals are a natural result of our long pioneering experience in the delicate art of crystal growing.

Harshaw Purity means light absorbing impurities are reduced to infinitesimal traces.

Harshaw Clarity gives highest possible transmission of the crystal's own emitted light.

Harshaw Activation means the optimum thallium concentration ensuring maximum energy conversion.

Our crystals are normally supplied hermetically sealed in aluminum containers engineered to secure maximum light collection. We will custom design these units to fit your specific requirements. Harshaw crystals are currently used in nuclear physics research, well logging, uranium prospecting, medical research, and industrial process and product control.

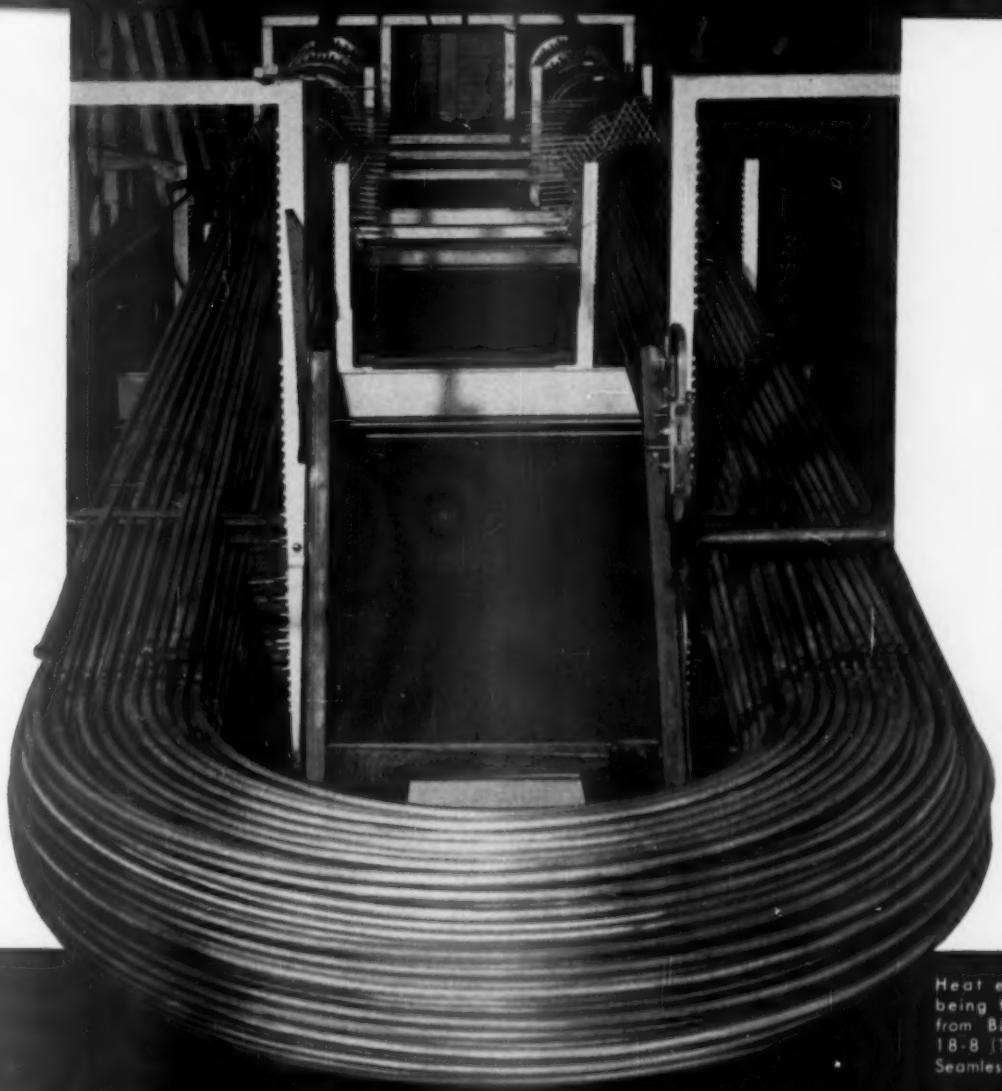
No need to specify "Harshaw Quality". . . you get it automatically when you order Harshaw Crystals. We encourage requests for technical assistance. Prices, specifications, or other information will be sent in answer to your inquiry.

OTHER HARSHAW SCINTILLATION CRYSTALS AVAILABLE IN THE FOLLOWING FORMS:

Potassium Iodide (Tl) • Cesium Iodide (Tl) • Cesium Bromide (Tl)
Anthracene • Stilbene • Naphthalene
Lithium Iodide (Eu) for neutron detection • Sodium Iodide (rough cut blanks)

THE HARSHAW CHEMICAL CO.

1945 EAST 97TH STREET • CLEVELAND 6, OHIO



Heat exchanger being fabricated from B&W Croloy 18-8 (Type 304) Seamless Tubing.

B&W TUBULAR PRODUCTS FOR NUCLEAR APPLICATIONS

In nuclear applications there are many and various conditions which tubular products must meet. These problems may involve the metal of which the tube is produced, the dimensional accuracy of the tube, its uniformity and soundness, its surface finish and cleanliness or the ease with which it can be further fabricated.

Supplying tubular products for nuclear applications since its beginnings, and for all phases—from the refining and production of fissionable materials, through the generation of energy by various types of reactors and other uses of fissionable materials—has given B&W engineers the background to cope with practically any set of circumstances.

That is why B&W Tubular Products of such materials as zirconium down through the standard and special stainless and alloy steels and carbon steels have found wide use in heat exchangers, piping and structural and mechanical parts. A call to Mr. Tubes, your nearby B&W tube representative can help solve your tubular problems in the nuclear field. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

TA-7012-PN1

Seamless and welded tubular products, seamless welding fittings and forged steel flanges—in carbon, alloy, and stainless steels.

A Decade of

NUCLEONICS September Anniversary Issue

From a laboratory phenomenon to a mushrooming industry in little over ten years is the unrivalled success story of our peacetime NUCLEAR industry . . . it is also the story of NUCLEONICS Magazine, whose growth has paced this expanding market.

In physical composition, the NUCLEAR industry is *unlike* any other . . . its people represent *every* known science and branch of engineering. And although they have widely varying backgrounds they display a *common* characteristic: a dependence on NUCLEONICS for news of important developments in products, services and techniques . . . information *tailored* to their *specialized* needs.

When NUCLEONICS was first published, in September 1947, these industry pioneers numbered only a handful. Today, in comparison, there are almost 16,000 paid subscribers to NUCLEONICS. Here is the audience your advertising must reach – the men who influenced the purchasing of nuclear products and services in 1956 . . . and who will exert a greater influence in 1957.

These readers will devote *more* than their usual amount of time to NUCLEONICS' September 10th Anniversary Issue . . . because it will tell the story of their *personal* accomplishments over the past 10 years . . . and will point up the promise of the next decade.

NUCLEONICS is a habit with important industry people . . . a long standing habit!

Check your schedule. Be sure September NUCLEONICS is included. (Forms Close: August 8th)

Research Report #81 contains new information about the NUCLEONICS Reader. Send for your copy.

NUCLEONICS **A McGraw-Hill Publication,** 330 West 42nd Street, New York 36, N.Y.

ABC ABP

ATOMIC POWER
NUCLEAR ENGINEERING
APPLIED RADIATION

Editorial Service

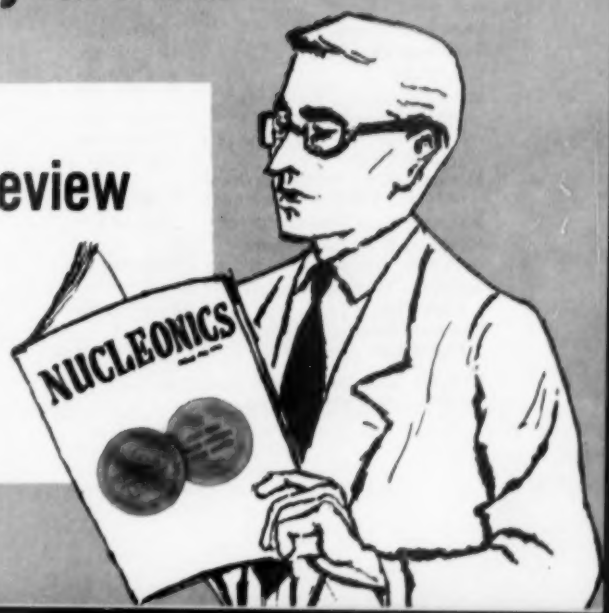
... to the expanding NUCLEAR market

Marks 10 Years of Industry Growth

NUCLEONICS Editorial Preview

September 10th Anniversary Issue

Titled "NUCLEAR ENERGY– 1947-1957; A Decade of Progress 1957-1967; A Decade of Promise" the issue will look ahead at the next decade in nuclear energy (what are the problems, the unknowns; what needs to happen; what is likely to happen).



Now available for your use

2 to 10 Mev Linear Accelerator

New Arco Western Service Irradiation Center for

research and product development
pilot scale studies
limited commercial processing

Now Arco offers you a completely equipped service center for experimental or pilot plant irradiation. Heart of the new Arco facility is a powerful Arco Mark 1-F4 linear accelerator providing a convenient, inexpensive-to-use source of X-ray, electron or neutron radiation. The Irradiation Center is available for single projects or continuing irradiation programs. Your technical personnel may plan, conduct and evaluate their own irradiation program; our staff assists as desired. Or, samples may be shipped to Arco for irradiation to specification and returned to you for evaluation.

Briefly, these are facilities Arco offers:

Electron Beam Energy	2 to 10 Mev
Electron Beam Power	Variable to 4 Kw
Dose Rate	Variable to 1.6 x 10^9 r/min.
Average Beam Current	700 μa
Peak Beam Current	200 ma
Beam Pulse Length	10 μsec
Pulse Repetition Rates	1 to 360/sec
Scan Width	3 to 18 inches
Maximum Electron Penetration (±20% dose variation)	
One side	3 cm water
Cross-firing	8 cm water
Maximum X-ray Penetration from one side (±20% dose variation)	20 cm
Maximum X-ray Intensity (at 18")	1.6 x 10^6 r/hr
Maximum X-ray Beam Power (6 Mev electrons)	700 watts
Maximum Total Neutron Production	1 x 10^{11}/sec
Maximum Thermal Neutron Production	5 x 10^8/cm^2/sec

Chemical laboratory, vacuum line, dosimeters, industrial gases, machine shop.

New brochure describing Service Center facilities sent on request.

New Arco Irradiation Center is at Walnut Creek, California, 25 miles from San Francisco.

APPLIED RADIATION CORPORATION
Walnut Creek, California, U. S. A.
Cable "ARCO" YEllowstone 5-2250

LITHIUM

HIGH ENERGY

fuel for thought

THE fuel-propellant of the future may prove to be an inorganic material, with metallic properties, capable of releasing tremendous heat burning capacity. Such an inorganometallic will likely contain a compound of *lithium*. For *lithium* offers uniquely valuable properties . . . properties that aid in contributing an unusually high power-to-weight ratio so necessary for military missiles and rockets.

Lithium, for example, combines low density with high heat of combustion to give a much sought after ratio of extraordinary chemical energy per unit of weight. On this score alone it proves of inestimable value.

Will these properties improve your product?

. . . low density
. . . high heat capacity
. . . high heat of fusion
. . . chemically reactive
. . . low melting point
. . . high flash point
. . . easily cut with a knife
. . . ductile, can be extruded and rolled
. . . readily melted or cast
. . . lighter than magnesium or aluminum
. . . can be dispersed in suitable media

Consult our PR&D department on your use-research problems. Up-to-date Product Data Sheets plus laboratory quantities of lithium metal, metal dispersions, metal derivatives and salts are yours for the asking.

. . . trends ahead in industrial applications for lithium

LITHIUM CORPORATION OF AMERICA, INC.
2595 RAND TOWER, MINNEAPOLIS 2, MINN.

member of...

PROCESSORS OF LITHIUM METAL • METAL DISPERSIONS
METAL DERIVATIVES: Amide • Hydride
SALTS: Bromide • Carbonate • Chloride • Hydroxide • Nitrate
SPECIAL COMPOUNDS: Aluminate • Borate • Borosilicate • Cobaltite • Manganite Molybdate • Silicate • Titanate • Zirconate • Zirconium Silicate

BRANCH SALES OFFICES: New York • Chicago • Bessemer City, N. C.
MINES: Keystone, Custer, Hill City, South Dakota • Bessemer City, N. C. Cat Lake, Manitoba • Amos Area, Quebec
PLANTS: St. Louis Park, Minnesota • Bessemer City, N. C.
RESEARCH LABORATORY: St. Louis Park, Minnesota

Setup for 1500° F creep test proves...

Inconel "X" withstands sustained high temperature and stress

What alloys creep the least when exposed to continued high heat and corrosion?

To find out, metallurgists use the setup shown. They grip one end of the alloy specimen (*A*) with a fixed rod (*B'*), grip the other with a loaded rod (*B''*) free to move. To measure creep, they periodically gauge separation between collars (*C*) set-screwed to specimen. During the run (often months or years) temperature is carefully controlled.

Hard on specimens . . . harder on the grips and collars

In the test, the alloy used for grips and collars acts as a "gentleman's gentleman". . . stays with the specimen till failure. Then does it again and again with specimen after specimen.

In the 1200° — 1500°F range, Inconel "X"* age-hardenable nickel-chromium alloy is widely used for these grips and collars.

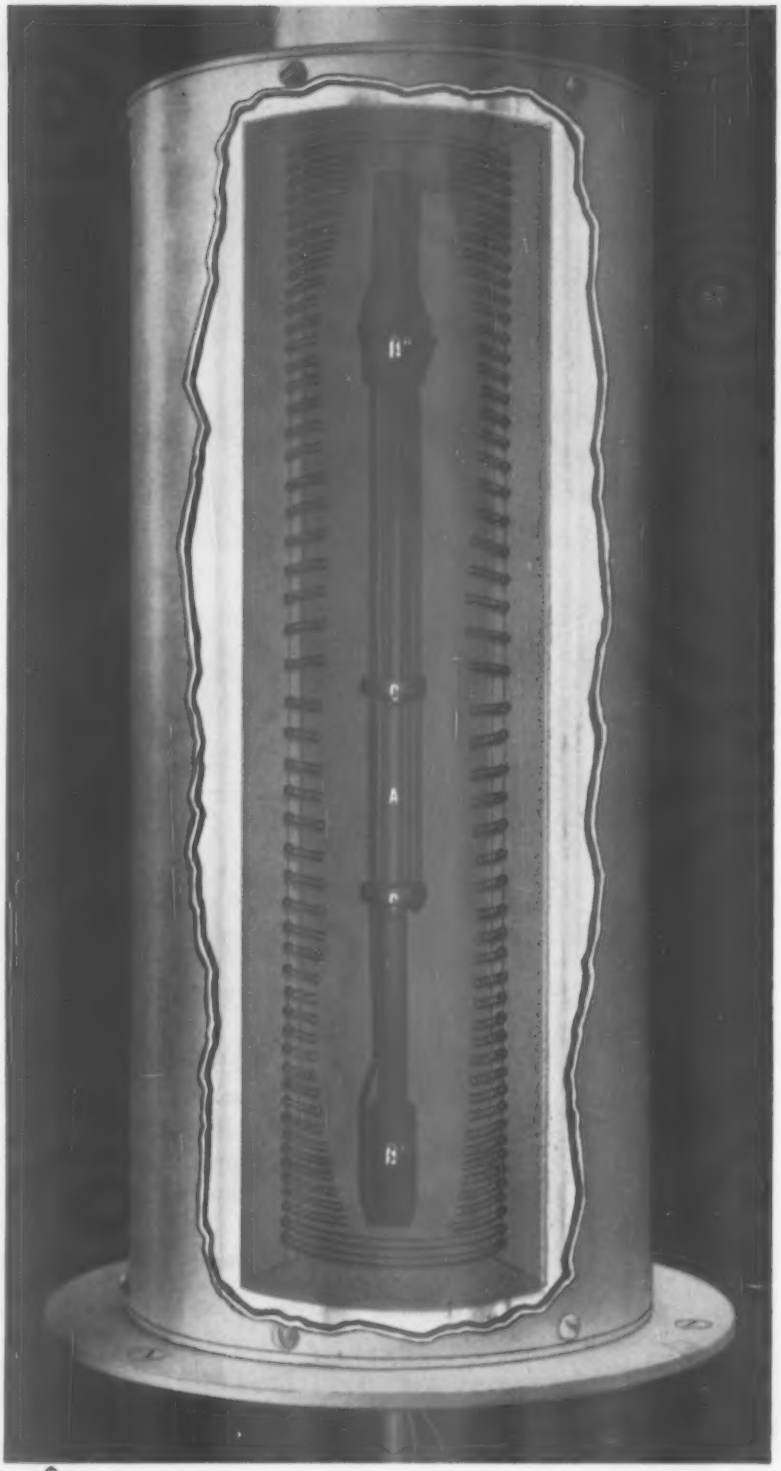
Endurance of alloy leads to its use for nuclear equipment

Wherever highly stressed structurals must function up to 1500°F, Inconel "X" alloy is often specified. It provides 100-hour rupture strength as high as 29,000 psi at 1500°F. It also offers outstanding structural, mechanical and chemical stability; excellent spring properties at temperatures up to 1000°F; high resistance to galling and abrasion; low coefficient of expansion; low creep.

Get a complete rundown on Inconel "X" alloy, its properties and use. Write for 79-page Inco booklet, "Inconel 'X'."

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.

Does Inco make other low-creep high-strength heat-resisting alloys?
Yes! Other excellent Inco Nickel Alloys are produced. Still others are in research. Inco's Development and Research Division will be glad to advise on the use of these alloys. Just write.
*Registered trademark



INCO TRADE MARK Nickel Alloys

Inconel "X" *for long stress-rupture life at high temperatures.*

Characteristics of EBWR

Location:	Argonne National Lab. (ANL), Lemont, Ill. (operated by Univ. of Chicago for AEC)
Architect-engineer:	Sargent and Lundy
Major suppliers:	ANL (fuel elements, core structure, control rods, control rod drives, fuel handling equipment) Allis-Chalmers (turbo-generator, condenser, main pumps, transformer and switchgear) Babcock & Wilcox (pressure vessel, steam dryer) Graver Tank & Mfg Co. (containment shell)
On line:	December 29, 1956
Output—heat:	20,000 kw
—electrical:	4,500 kw

Component Design Data

Pressure vessel

Inside height:	23 ft
Inside diameter:	7 ft
Wall thickness:	2.25 in.
Composition:	carbon steel
Cladding:	
—material:	stainless steel (304)
—thickness:	0.109 in.
Design pressure:	800 psig
Test pressure:	1,200 psig

Core

Configuration:	right cylinder
Size:	4 ft dia × 4 ft
Location*—bottom:	10.3 ft
—top:	14.3 ft
Fuel load—U^{235}:	76.4 kg
—U^{238}:	5,594.2 kg
Composition	
—water:	65.3 vol%
—uranium:	18.6 vol%
—Zircaloy:	15.4 vol%
—niobium:	0.7 vol%

Control rods

Configuration:	cruciform
Number	
—hafnium:	5
—boron steel:	4
Composition	
—boron steel:	2 wt% B in 304 SS
Total rod worth:	13% $\Delta k/k$
Absorber length:	46 in.
Follower length:	129.5 in.
Follower material:	Zircaloy-2
Weight	
—Hf rod:	97 lb
—B rod:	141 lb
Withdrawal rate:	28 in./min
Avg. scram time:	0.35 sec

Control rod drives

Type:	lead screw and nut
Number:	9
Power:	440 v, 3ϕ
Motor rating:	68 rpm, ⅓ hp
Position-indicator accuracy:	±0.025 in.

Fuel elements

Type:	plate
Number	
—enriched:	106
—natural:	8
Enrichment:	1.44%
Plates per element:	6
Meat dimensions	
—thin plate:	51 × 3.31 × 0.172 in.
—thick plate:	51 × 3.31 × 0.240 in.
Meat composition	
—U:	93.5 wt%
—Zr:	5.0 wt%
—Nb:	1.5 wt%
Cladding:	Zircaloy-2
Plate temp.—avg:	497° F
—max:	645° F

* Above bottom of vessel, along centerline.

Nuclear Design Data

Moderator

Type:	light water
Average neutron energy:	0.046 ev
Thermal flux	
—avg.:	1.0×10^{13} n/cm²/sec
—max.:	2.4×10^{13} n/cm²/sec
Prompt-neutron lifetime:	6.26×10^{-5} sec
Eff. delayed-neutron fraction:	0.0085
Over-all temp. coefficient:	-1.9×10^{-4}/° F

Control requirement

Burnup:	1.5% $\Delta k/k$
Equilibrium xenon:	2.2% $\Delta k/k$
Equilibrium samarium:	0.75% $\Delta k/k$
Temp. coefficient:	0.65% $\Delta k/k$
Voids:	2.0% $\Delta k/k$
Total	7.1% $\Delta k/k$ (~ $10)

Heat Transfer Data

Coolant

Type:	light water
Height*	
—nonboiling:	11.9 ft
—boiling:	2.4 ft
Total volume:	955 liters
Volume in core:	790 liters
Inlet flow:	120 gpm
Inlet temperature:	110° F
Operating pressure:	600 psig
Outlet steam temp.:	488° F
Outlet steam flow:	60,600 lb/hr
Recirculation rate:	63 lb/lb of steam

Heat flux

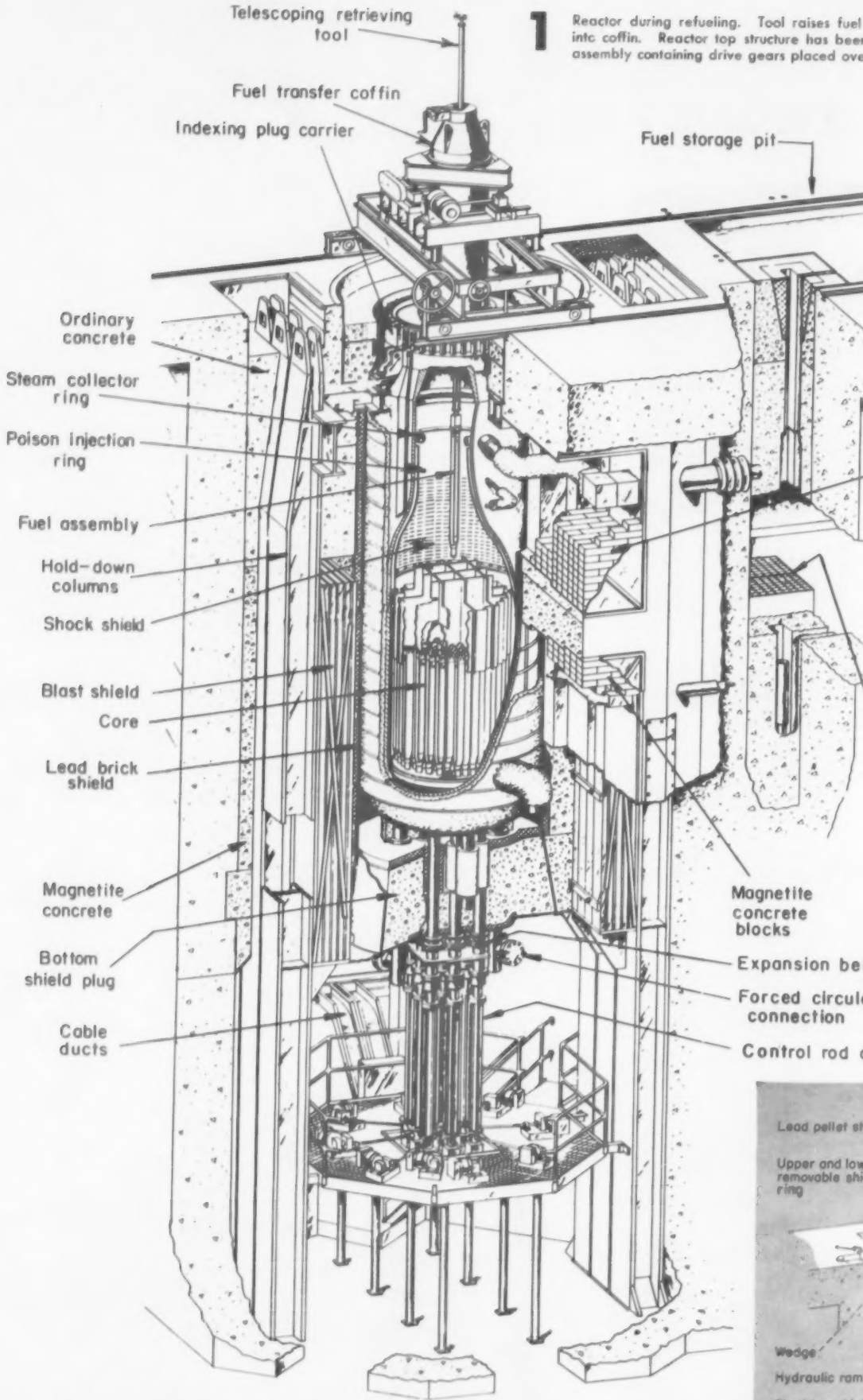
Max/avg ratio	
—axial:	1.49
—radial:	1.58
Core—average:	45,500 Btu/hr/ft³
—maximum:	141,000 Btu/hr/ft³
—burnout:	750,000 Btu/hr/ft²

NUCLEONICS REACTOR FILE... NO. 1

Reactors on the Line

EBWR

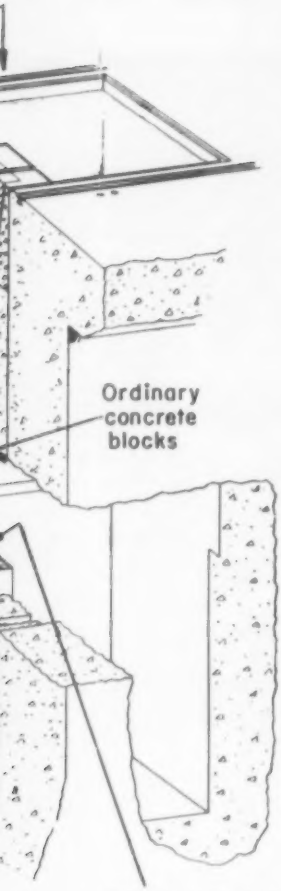
Experimental Boiling Water Reactor



1 Reactor during refueling. Tool raises fuel into coffin. Reactor top structure has been assembly containing drive gears placed ove

Contents copyrighted under the general copyright on the July 1957, issue—NUCLEONICS, 330 W. 42nd St., New York, N. Y.

ses fuel assembly out of core
as been removed and carrier
ced over indexing plugs

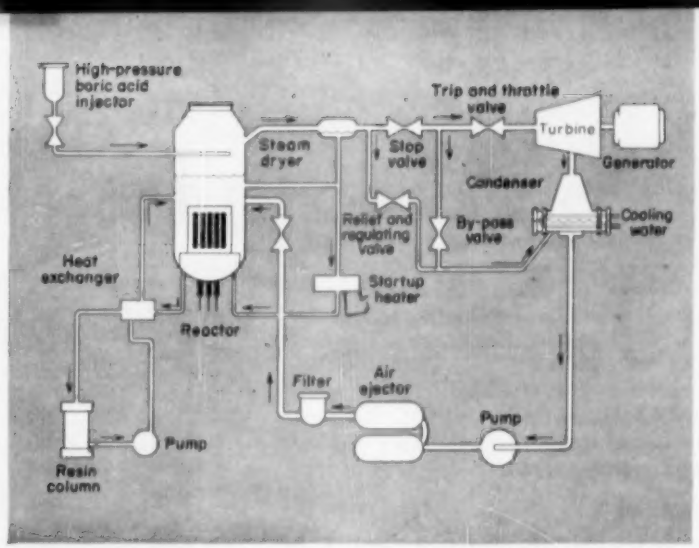


te
e

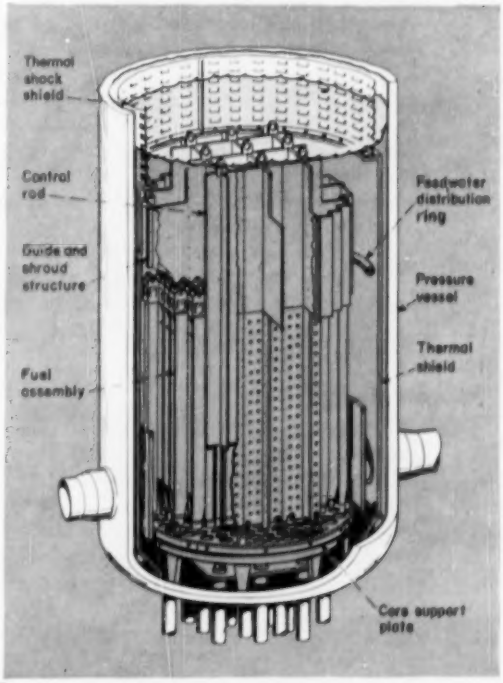
sion bellows

l circulation
ction

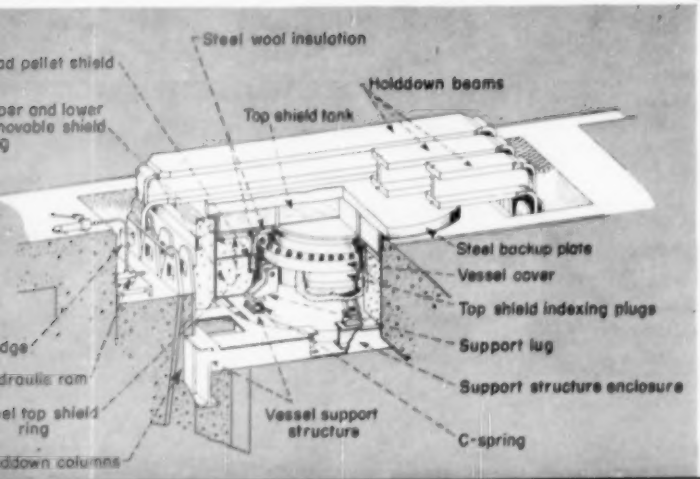
ol rod drives (9)



2 Schematic flow diagram. Saturated steam flows from reactor through steam dryer to turbine. Excess is bypassed around turbine, through de-superheater, to maintain constant reactor pressure. Auxiliary emergency shutdown is provided by high-pressure boric-acid injection system (upper left). Feedwater control is by water purification system (lower left)



3 Core structure locates upper ends of fuel assemblies, prevents mixing of inlet feedwater from distribution ring with coolant exiting from core channels, guides control rods as they move in core



4 Top of reactor during operation. Vessel is supported on C-shaped compression springs resting on framework attached to three columns on either side of reactor. Three hold-down beams are pinned by wedges to top of columns

Description of EBWR

The Experimental Boiling Water Reactor (EBWR) is a heterogeneous, direct-boiling, natural-circulation nuclear power plant designed to acquire information on the uncertainties associated with direct reactor-turbine coupling. Prominent among these uncertainties are radioactivity carryover, reactivity-feed-back effects, corrosion, erosion, leakage and feed-water quality control.

The EBWR is not optimized to produce economic electricity. Rather, it is a flexible experimental tool intended to provide as much information as possible for designing future central-station power plants. For example, the 4-ft-diameter core can be increased to 5 ft, fuel elements of different dimensions permit changing the water-to-uranium ratio to study the influence of steam-void coefficient of reactivity on reactor stability, and two different enrichments of uranium permit the critical size and power-distribution pattern to be varied.

Later, forced circulation will be employed to increase the power output and to study its effect on reactor stability. In addition, it is planned to replace the present core with one for use with a heavy-water moderator.

Pressure Vessel and Shielding

The pressure vessel consists of an upper ring forging; a two-course, rolled-plate shell; and a spun-plate lower head. A flat cover plate is held in place against the two sealing gaskets by 44 bolt studs screwed into the ring forging. The over-all vessel length is 30 ft 11½ in.; dry weight (including thermal and shock shields and cover plate) is approximately 65 tons.

The pressure vessel is surrounded by 3 in. of stainless steel–wool insulation, a 3-in. air space and a carbon steel tank. The tank has cooling coils on its outer surface and is surrounded by lead brick and a plaster containing ferroboron as part of the fine aggregate. The space between the plaster and the concrete octagonal shell that surrounds the reactor is filled with magnetite concrete with steel punchings intermixed, plain magnetite concrete, or ordinary concrete, depending on the radiation intensity. Total shield thickness is 8 ft 3½ in.

The shielding below the pressure vessel is magnetite-steel-punching concrete with the addition of layers of lead and ferroboron plaster in critical areas. The perforations for the nine control-rod-drive thimbles and the four discharge nozzles for future forced circulation are stepped to prevent direct radiation streaming.

At the top of the reactor, shielding is provided by the stainless steel indexing plug assembly, the pressure vessel cover and a portable water tank. The space surrounding the vessel-support lugs, indexing-plug assembly and vessel cover is partially occupied by magnetite-steel-punching-concrete blocks, steel plates and a container of lead pellets.

Reactor Core Structure

The structural components of the core are the control-rod guide, top shroud structure and the core support plate and legs.

The control-rod guide is fabricated in two sections. The lower section, being in the active core region, is constructed of ⅛-in. Zircaloy-2 sheet angles 60 in. high. The upper section is constructed of ⅛-in. type 304 stainless steel sheet angles 47 in. high. The use of angle shapes results in an easily assembled structure that divides the core into cells with cross-shaped control rod guide channels at the corners of four adjacent cells.

The top shroud structure fits around, and is riveted to, the upper section of the rod guide. It is constructed of ⅛-in. type 304 stainless steel sheet 34 in. high. The bottom of the shroud is on a level with the bottom of the rod-guide upper section.

The core support plate is a type 304 stainless steel forging 5 ft in diameter, 5¾ in. thick. The plate contains 9 cross-shaped control-rod slots and 148 fuel assembly location holes. It also contains forty ⅞-in.-dia tapped holes for bolting the control rod guide to the support plate.

Control Rods

The 5 hafnium-Zircaloy rods are fabricated from ⅛-in. sheet bent into angles and spot-welded together to form a 10-in. by 10-in. cruciform. The boron-steel absorber section of the 4 rods of this type are fabricated from ⅛-in. sheet. The Zircaloy-2 follower section of this type rod is fabricated from ⅛-in. sheet, as before, with a ¼-in. Zircaloy-2 filler plate to bring the total thickness up to that of the absorber section (¼ in.).

The purpose of the Zircaloy-2 follower section in each type of control rod is to fill the rod guide with a material of low absorption cross section when the absorber section is withdrawn from the core.

Control-Rod Drive Mechanism

All operating parts of the nine control-rod drive mechanisms are external to the reactor vessel. The main components of this drive are the connector and seal assembly, main housing assembly, drive motor and shaft assembly and position indicator.

The connection between the control rod and the lead screw is made in the connector seal assembly by a chrome-plated stainless steel extension rod through a pressure-breakdown controlled-leakage seal. Seal leakage is replaced by 110° F feedwater through the connection on the reactor thimble just above the flange. The extension rod is connected to the control rod by a bayonet-type joint.

The main housing assembly contains the lead screw, latch carriage and dashpot. The SAE 660 bronze latch carriage is a platform for the roller latch, latch magnet and latch-indicating switch. The carriage is driven by the 1¼-in. acme-thread SAE 4340 steel lead screw.

When the rod is released from the carriage (as in a scram), the drive motor automatically returns the carriage to pick up the rod. Torque is transmitted from the motor to the three-way angle drive shaft attached to the lead screw by an adjustable clutch and universal-joint tube.

Position indication is achieved through a synchro transmitter and receiver, with the transmitter being driven by the lead screw through a 50:1 high-precision reduction gear.

Fuel Assembly

The fuel assembly consists of a lower locating end fitting, six fuel plates, two side plates and a top fuel-handling fitting. The locating end fitting is machined out of a stainless steel tube with a 3⅞-in. o.d. The fuel plate is fabricated in two thicknesses. One type is 54 in. long, 3⅜ in. wide and 0.212 in. thick. The other type has the same length and width but is 0.280 in. thick.

The side plates are constructed from Zircaloy-2 sheets. They are perforated to provide a low tensile strength without necessitating making them so thin that welding to the fuel plates would be difficult. A low tensile strength is desirable to permit possible radiation-damage growth and/or differential thermal expansion of the fuel plates to be absorbed by the assembly with the minimum of restraint on the fuel plate.

The fuel-handling fitting is constructed of ⅛-in. stainless steel sheet. The cutout flaps extending from the sides of the fitting form springs to space the assemblies uniformly in relation to each other and to the control-rod guide.

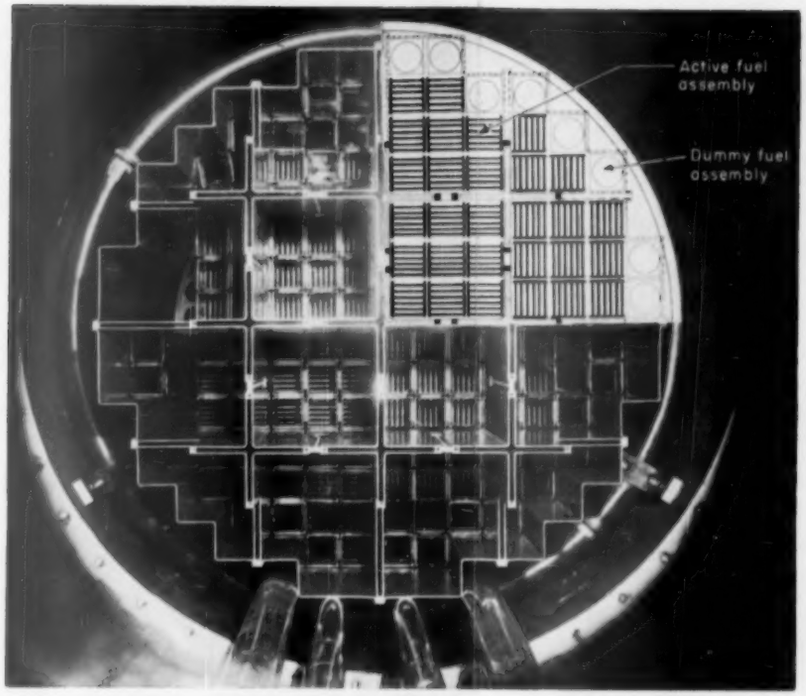
Safety Features

The entire power plant as described thus far is housed within a cylindrical steel shell having an ellipsoidal bottom and a hemispherical top. The shell is 80 ft in diameter and 119 ft high, with about one-half the height below ground level. It is lined with concrete up to a steel-plate-and-concrete ceiling under the dome.

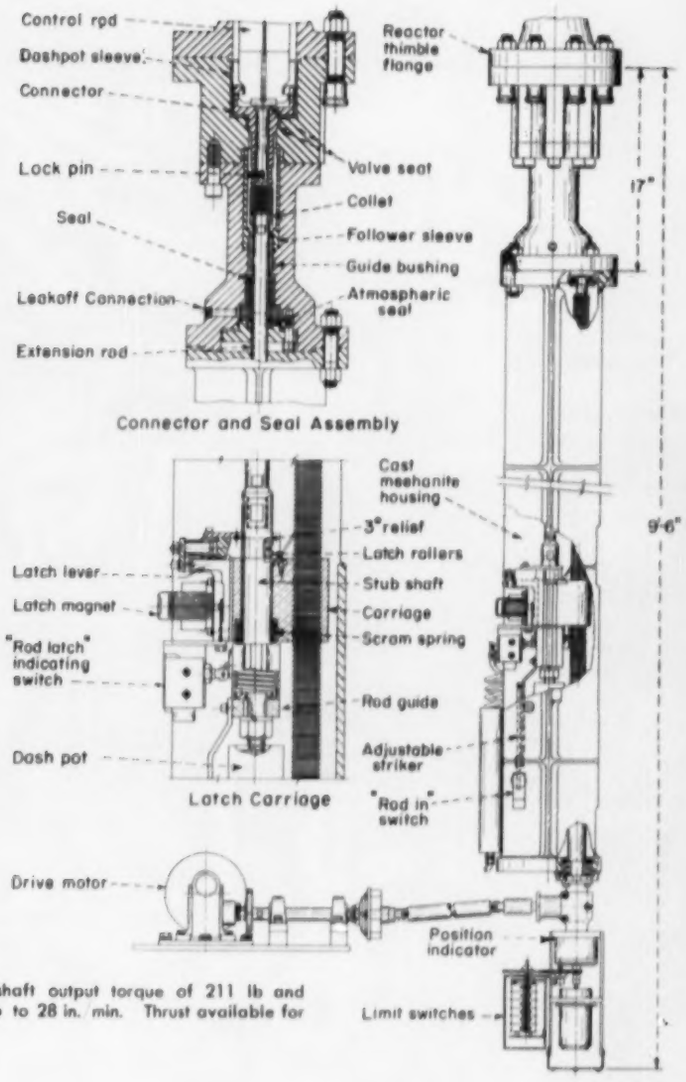
To prevent excessive pressure buildup in the shell because of steam release, a spray system has been provided to spray water into all parts of the shell to condense any steam released. The system is supplied from a 15,000-gal tank located in the dome above the ceiling.

The reactor structure is designed to prevent a catastrophe in the event of an explosive zirconium-water reaction within the core. The shock pressures developed would cause the bottom head of the vessel to blow, together with the bottom shielding, into the basement. The large upward force developed would be restrained by the three hold-down beams across the top of the reactor. Laminated blast shields of compressible material and steel are interposed between the reactor and the columns (in vicinity of the core) to protect the latter from side shear.

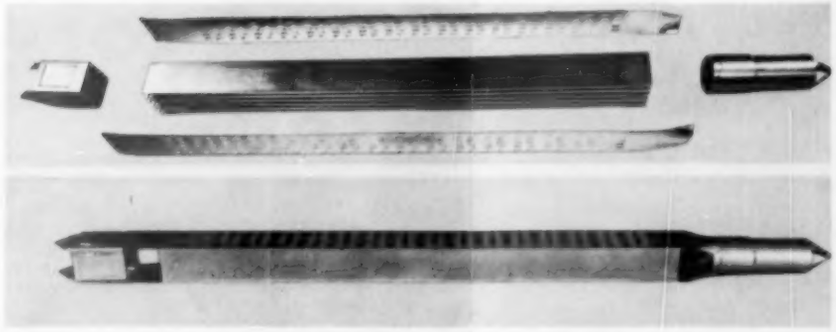
More Views of EBWR



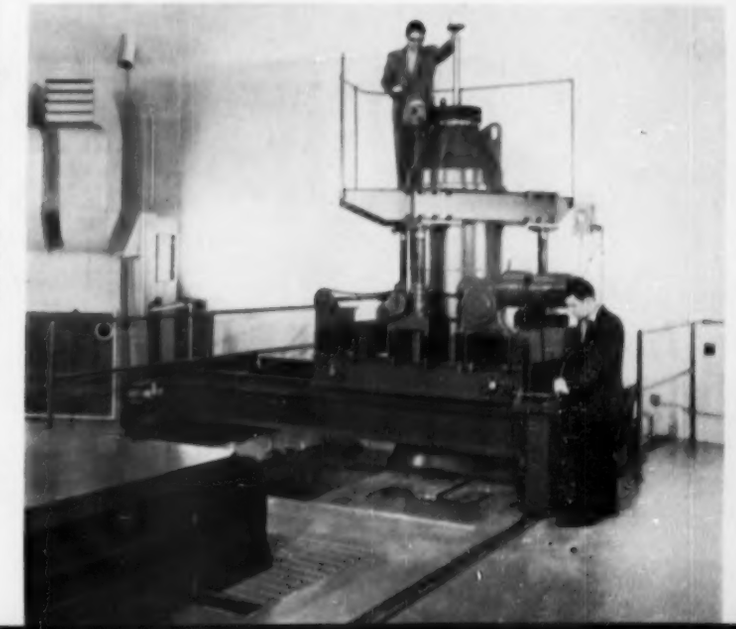
5 Actual photograph of core as it was being loaded to criticality. Fuel assemblies are lowered one by one, working outward from center. Insert shows core-loading pattern when completed



6 Control drive gear motor provides shaft output torque of 211 lb and auxiliary gear train adjusts speed up to 28 in. min. Thrust available for driving extension rod is 3,350 lb

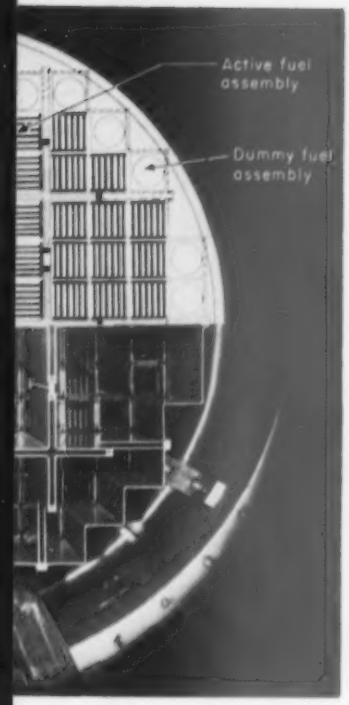


7 Six-plate fuel assemblies are 77⅝ in. long, 3¾ in. square. Zircaloy-2 cladding dimensions are: 0.020 in. on sides, 0.125 in. on edges, 1.5 in. on ends. Dummy assemblies closely resemble active ones except dummies are empty shells with $\frac{1}{16}$-in. Al-Ni walls

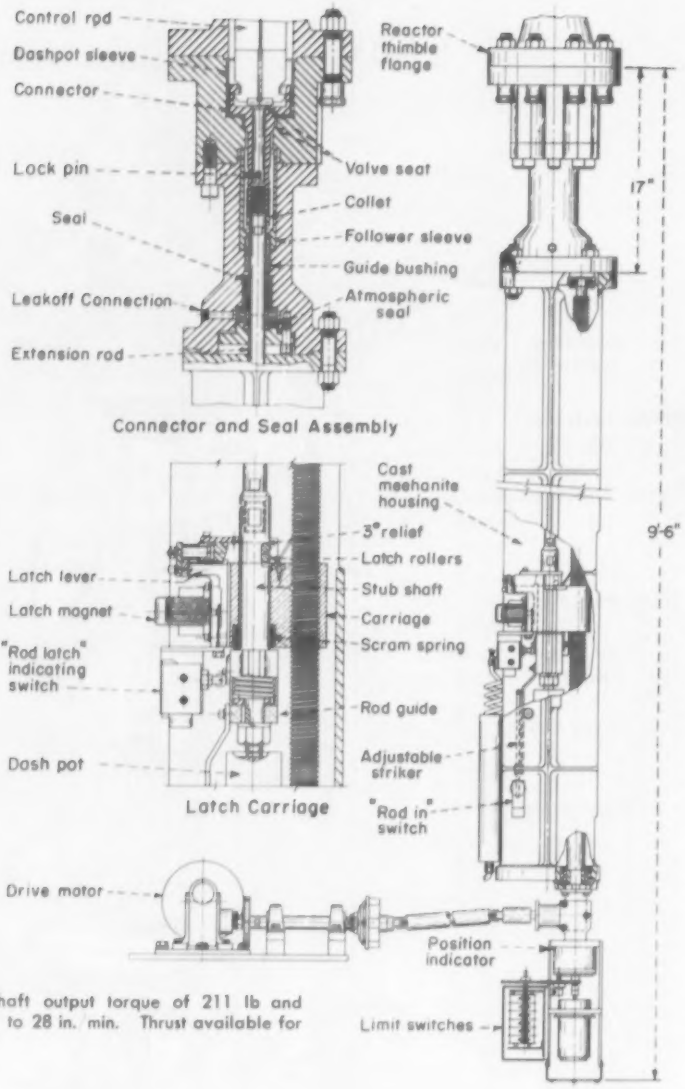


8 Fuel transfer coffin rides on tracks between reactor and fuel storage pit. Coffin is 30-in. o.d. lead cylinder sheathed in 1-in. steel. Retrieving tool is raised and lowered by manually operated winch

f EBWR



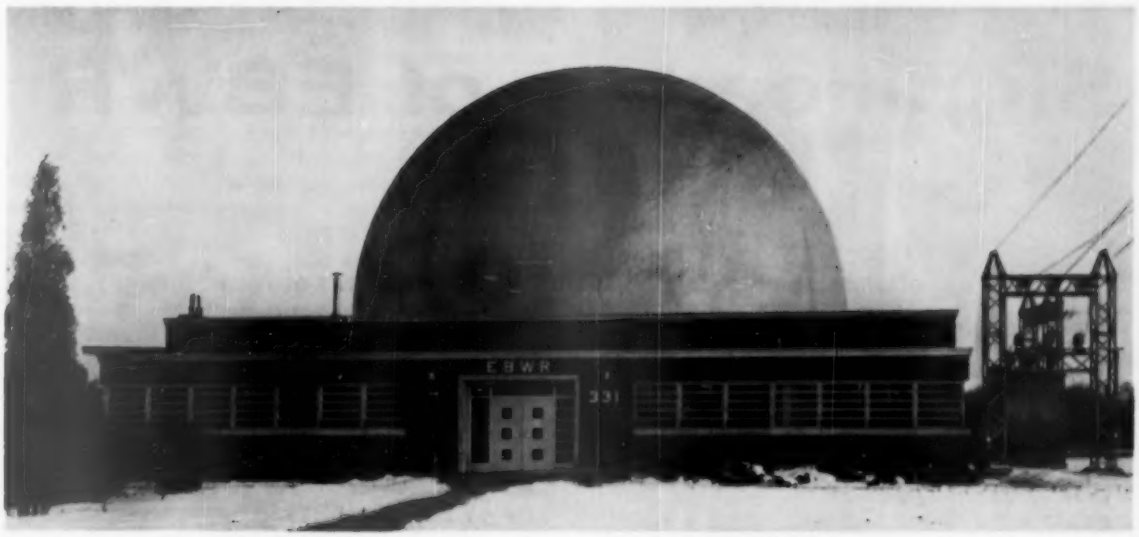
ed to criticality. Fuel assemblies are
er. Insert shows core-loading pattern



6 Control drive gear motor provides shaft output torque of 211 lb and auxiliary gear train adjusts speed up to 28 in. min. Thrust available for driving extension rod is 3,350 lb

uare. Zircaloy-2 cladding dimensions are:
nds. Dummy assemblies closely resemble
$\frac{1}{16}$-in. Al-Ni walls

or and fuel storage pit. Coffin is 30-in.
ng tool is raised and lowered by manually



EBWR Operating Experience

What Happened p.60

Snow was on the ground when the Experimental Boiling Water Reactor first generated electric power to serve the needs of Argonne National Laboratory, where it was built. Since that day in late December EBWR has run at full power much of the time, generating in excess of 5,000 Mwh total. The operating experience gained in these first months is detailed by Joseph Harrer, leader of the EBWR project, in an article beginning on p. 60. In brief the operating experience has been good . . . the plant has proved stable and reliable.

What About Costs? p.58

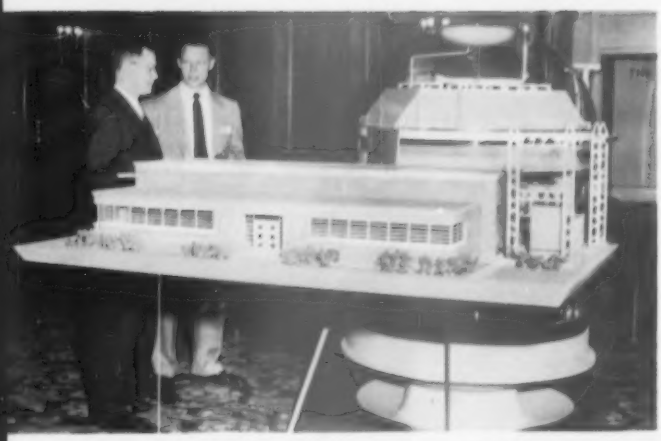
Much attention centers on the cost of the power that EBWR generates. Here the recognition that it is primarily an experimental reactor helps take the sting out of the fact that a straightforward assignment of capital and operating costs leads to a figure of 52 mills/kwh. Coincidentally, this cost figure is identical with that expected for initial operation of the Shippingport Pressurized Water Reactor (NU, Jan. '57, p. 14). In both cases cost figures will decrease radically with improved design and higher-power operation.

What It Means p.54

What the EBWR operating experience means for the nuclear power industry in general and boiling-water reactors in particular is summarized in the article beginning on p. 54. This commentary, based in part on interviews with EBWR project members, reveals that the problem of matching steam demand has been met and that only a better understanding of resonance instabilities stands in the way of complete assurance about this reactor type.

Significance of EBWR

EBWR experience has already answered many questions of feasibility for boiling-water reactors and for reactor power plants in general. The question of resonance instability, however, still remains



EBWR MODEL is explained to visitor by William Kann of Argonne National Laboratory at the technical briefing session on EBWR held in May for participants in AEC power program

NORMAN HILBERRY, director of Argonne, and Joseph Harrer (left) discuss EBWR model. Harrer is leader of EBWR project and author of article on p. 60 about EBWR experience

EBWR first began full power operation December 29, 1956. Since that time the people who designed and built it have had a chance to observe just what sort of beast they have created. Their conclusions were recently made known with appropriate pride at an unclassified technical information meeting, sponsored by Argonne National Laboratory and attended by 250 international representatives of civilian atomic power. Their findings included these significant points:

- EBWR can produce electricity on a basis that would satisfy normal utility operating practices.
- EBWR has proven that boiling-water reactors can produce stable power under a varying demand load.
- Turbine contamination in a direct steam cycle appears so far not to be a worry.
- The major concern of the boiling-water reactor concept today is the possibility that resonance instability may prove to be an inherent characteristic.

Power-Plant Operation

Norman Hilberry, director of the laboratory, summed up the feeling of the staff about EBWR operating experience in his opening remarks on the morning of May 27: "The reactor itself behaves beautifully. It's the plumbing and standard equipment that gives us the headaches." EBWR has not so far run into any major operational difficulties. All the troubles have been with things like air leaks in the containment shell and tube failures in standard electronic chassis.

To date the reactor has manufactured a total of 5,000 Mwh of electricity, most of this during extended runs at full power (5 Mw electric). EBWR regularly supplies ANL with a substantial part of the laboratory's power needs during the day and can take over the full load at night. In performing this service the reactor plant operates in parallel with a local utility network and uses standard electric power operating equipment.

The EBWR experience is significant in that this is the first reactor in this country to go all the way as a power reactor. EBWR is generating a sizeable amount of electric power on a basis that would satisfy the everyday re-

quirements of load and reliability expected of a commercial power station. At the same time the EBWR plant successfully provides all of the elaborate safety precautions demanded of a power reactor that is to operate in a populated area. This is by no means a minor achievement. As anyone who has tried to build a reactor knows, the safeguards required tend to make all reactor systems designer's nightmares. EBWR, for instance, includes as safety features such things as an absolute reactor container—an all-welded steel shell 119 ft high and 80 ft in diam, a 15,000-gal tank of emergency water suspended at the top of the dome, two emergency boron injection systems, and provisions for completely remote operation outside of the containment shell.

Anyone looking at the plans for the maze of mechanical and electrical safeguard devices that go with the reactor might well question whether such a complicated system could ever be built much less operated as a commercial power plant. The achievement of the EBWR engineers is that first of all they have successfully transformed the complete reactor power plant, safeguards and all, from lines on paper into functioning hardware. Then they have gone ahead to show that this hardware can actually be run to produce power with a reliability that would satisfy commercial demands. Further they've succeeded in reducing the operation and maintenance of the plant to a set of routine procedures such as might be found in a conventional power plant.

J. Harrer, project supervisor for the EBWR, stressed the point that technicians without college backgrounds have been trained as operators and that for the last few months these people have been given the responsibility of routine operation and maintenance.

The final conclusions are that operational reactor power plants can be built near populated areas, they can produce commercially acceptable power, and they will not require a staff of Ph.D.'s to run them.

Steam-Demand Stability

One of the concerns of the boiling-water-reactor concept has been that the reactor is fundamentally unstable to changes in steam demand. A sudden increase in steam demand tends to shut the reactor down while a sudden decrease has the opposite effect. (This happens because, for an increase in steam demand, the reactor system pressure drops and the steam voids in the core expand thus reducing the reactivity.)

The EBWR engineers designed around this problem by installing a special by-pass throttle in a steam line that goes directly to the main condenser, by-passing the turbogenerator. The bypass throttle mechanism maintains a constant reactor system steam pressure by automatically adjusting the bypass flow rate to compensate for changes in turbogenerator steam demand. In practice the steam bypass device is used to hold steam pressure constant until the reactor power level can be adjusted to the new load condition. The performance of the steam bypass control system in EBWR has, so far, been quite satisfactory. EBWR has thus shown that boiling-water reactors can be designed to avoid steam-demand instability.

Although technical feasibility has been established the economic feasibility of the EBWR bypass system is not yet clear. Since the bypassed steam represents wasted energy, this method of control will always reduce the overall efficiency of the reactor plant. The question as to whether or not this loss of efficiency will prove to be serious is still to be answered.

The EBWR engineers however are optimistic about this point. They believe that under ordinary conditions it will prove to be feasible to operate the plant with the steam bypass valve completely closed. They feel the bypass will be mostly used as a convenient safety valve for relieving pressure buildup under abnormal circumstances.

STEAM BYPASS mechanism is pointed out by Walter C. Lipinski of Argonne for visitors touring EBWR during briefing

Turbine Contamination

Another reason for building EBWR was to test the feasibility of using the primary-circuit steam in a direct-turbine cycle. The possibility that radioactive contamination of the turbine might cause drastic problems of maintenance is usually quoted as one of the major concerns of the direct-cycle concept. Surprisingly little concern, however, was shown by the EBWR staff about this potentiality. The turbine was recently examined and showed no signs of contamination. Although there is some chance

Radiation Levels No Problem

An example of a pre-operational worry that did not materialize in actual operation was the possibility of prohibitive radiation levels around the reactor system while running at full power. Checks have shown that the gamma radiation level with the reactor at 20 Mw is lower than the most optimistic predictions. Practically all of the observed level is believed to come from radioactive decay of N^{16}(half life 7.4 sec) formed in the water by an *n-p* reaction. The following levels were measured at a few representative points in the reactor building:

Place	*Gamma-ray level (mr/hr)*
Top of reactor	1
Sub-reactor room	10
Steam dryer	150
Turbine inlet	50
Turbine casing	4
Condenser (above hot well)	40
Air ejector after cooler	400
Feedwater filters	5–100
Ion exchanger pre-filters (in shield)	500–100
Ion exchanger (in shield)	500–1000
Ion exchanger after filters	Low
Stack exhaust duct	3

that contamination will build up over a much longer period of operation, the feeling is that there will probably be no major difficulty. The staff does not plan to make any direct tests of turbine contamination (i.e., deliberate release of radioactivity into the system).

Resonance Instability

Boiling water reactors have recently run up against another kind of instability, known as resonance instability, that promises to be harder to cope with than the power-demand instability discussed above.

Resonance instability shows up in a reactor as spontaneous oscillations in reactor power that begin when the reactor power reaches a certain level. If the reactor power level is raised above this point the oscillations become larger in magnitude. A reactor known to have a resonance is then limited to an operating power a reasonable distance below the resonance power.

Resonance instability is believed to be the result of feedback between reactivity and reactor power. Feedback of this kind is present in all power reactors. However a resonance occurs only under special circumstances—when the reactor design is such that the phase relationship between reactivity and power can satisfy certain requirements.* This situation is not ordinarily found since most of the reactors built so far appear to be free of any resonance instability. However resonance behavior *has* been observed in both boiling-water and fast power reactors. In the latter instance there is hope that the resonances can be removed by changing the mechanical design (NU, Apr. '57, p. 65). The problem for the boiling-water reactor appears to be more difficult.

The central fact is that all of the boiling-water reactors built and operated so far have shown evidences of resonance instability. Although the exact causes are not yet understood, the presence of steam voids in the core is believed to be essential to the existence of the resonances. (Since the steam void size depends on power and in turn influences reactivity, the voids act as a feed-back mechanism between power and reactivity.) Both Harrer and J. Thie, director of physics for EBWR, make the point that previous experience with the Borax reactors showed that, as a rule of thumb, instability could be expected when the amount of reactivity controlled by the steam voids is greater than 2% in Δk. If this explanation is accepted then, since a boiling-water reactor has to operate with steam voids in its core, it follows that resonance instability is an inherent feature of this reactor concept.

Such a conclusion does not mean that boiling-water reactors are finished. Granting the possibility that every boiling-water reactor built might have a resonance, this fact can be ignored if the reactor can be designed so that the power at which resonance oscillations would start is a safe distance above the proposed maximum operating level. The immediate problem is to find out enough about the resonance phenomenon to design reactors in this way. A second problem is to develop a fool-proof method of testing reactors after they have been built to demonstrate that any resonance that might be present actually occurs far enough above the design power.

EBWR should provide considerable information on both of these problems. And in fact it will be one of the first reactors to benefit from this information. As things stand today the question of resonance instability is one of the major uncertainties facing the EBWR itself. So far two things are known from experience: (1) at low pressures (100 psig) oscillations which could be resonance oscillations

* If the reactivity is varied sinusoidally with frequency ω the reactor power will respond by performing oscillations of the same frequency. The relationship between the phase and amplitude of the power oscillations and the phase and amplitude of the imposed reactivity oscillations is given by the reactor response function, $G(i\omega)$. Thus $\Delta P/P_0 = \Delta k_0 e^{i\omega t}/G(i\omega)$. The reactor will be unstable (will break into spontaneous power oscillations) at a given power and operating conditions if $G(i\omega) = 0$ for any ω. The reactor is then said to have a "resonance."

The Plans for More Boiling-Water Reactors

Several boiling-water power reactor designs are following close on the heels of EBWR. Half of these will be built in foreign countries. All but two of them are being built to serve as commercial power plants.

G. E. Vallecitos Reactor. **The next boiling-water reactor to go critical will be the 5-Mw power plant constructed by the General Electric Co. at its Vallecitos Atomic Laboratory in California. The Pacific Gas and Electric Co. is providing and operating the generating portion of the plant. The reactor will be used to test out fuel and operating features of commercial boiling-water reactors. It is light-water cooled and moderated with either forced or natural circulation. The reactor has a design pressure of over 1,000 psi and can operate single or dual cycle. The first fuel element will be fully enriched UO_2-stainless-steel plates clad with stainless steel. The system is expected to go critical sometime later this year. (NU, Apr. '57, R24).**

Norwegian process steam plant. **A 3-Mw boiling-water reactor is under construction near Halban, Norway. This is a heavy-water, slightly enriched machine. The heavy steam is used in a condenser-boiler to produce ordinary light steam, the heavy-water condensate then returning to the reactor tank by gravity. The light-water steam is to be used for process purposes in a paper mill. The reactor is scheduled for operation early next year. (NU, Apr. '57, R26).**

The cost of building the plant ($3,000,000) is to be borne by the Norwegian government. The two major components of the reactor system are being manufactured in Norway. A/S Thunes Mek. Verksted is working on the heat exchanger while A/S Kvaerner Brug has the reactor pressure vessel job. The U. S., however, will supply the heavy water, Great Britain the U.

Dresden Power Station. **By far the largest boiling-water reactor project being pursued today is the 180,000 kw forced circulation, dual-cycle power plant that G. E. is building for the Dresden Station of Commonwealth Edison near Chicago. This reactor will have a power output 36 times that of the EBWR. The engineering design is now about half done and will be finished by the end of 1958. The construction, however, is already under way (NU, June '57, R22).**

A dual cycle with forced circulation is used in the Dresden plant in order to attain rated output without exceeding allowable steam void limitations. G. E. expects to complete the reactor in 1960.

Latin American Reactors. **General Electric has signed contracts to provide two 12.5-Mw single-cycle boiling-water reactors. One will be built in Cuba and the other in Brazil. They will be cooled and moderated by light water and will use partially enriched uranium-oxide fuel. They will produce steam at about 600 psig and 500° F. The plants will be owned and operated by American and Foreign Power. The Cuban reactor will begin operation in 1959. (NU, Mar. '57, R9).**

ARBOR Facility. **Argonne National Laboratory has made a preliminary design of a test facility known as the Argonne Boiling Reactor Experiment (ARBOR). Arbor would be larger (200 Mw) and more flexible than EBWR. The reactor vessel is**

have been observed for a reactor power of 1 Mw while (2) at design pressure (600 psig) no resonance behavior is evident up to 20% over the design power of 20 Mw.

The fact that the value of the resonance power should increase with increased pressure fits in with the steam-void explanation of resonances. But the important thing is that no one knows yet at what power the resonance, if it exists, will occur at design pressure. In other words no one knows how much further EBWR can be pushed up in power before it runs into a resonance. It is known that the reactor can go to 24 Mw and arguments are presented as to why it might be safe to go to 40 Mw. But no one is absolutely certain that the resonance could not be as high as 300 Mw or as low as 30 Mw.

Except for this single difficulty the reactor itself is not at all power-limited. Thie estimates that the power density can be increased by a factor of 6 or 7 before reaching the "burnout" heat flux. Increases of almost this much will be necessary if the EBWR or its successors are to be economically feasible (see page 58). Thus finding the safe upper limit of power for the EBWR from the point of view of resonance instability, is something that will throw light on the economic future of all boiling-water power reactors.

Future Program

A detailed plan exists for investigating EBWR in the months ahead.

The immediate objective is to find out everything possible about the question of resonances. This will be done by using the reactor oscillator technique. Small sinusoidal oscillations of reactivity will be imposed on the reactor by oscillating a control rod. Measurements of the amplitude and phase lag of the resulting reactor power oscillations will give information about the existence of resonances at higher powers without having to endanger the reactor by going to the higher powers. Tests will be run to determine the influence of all the relevant parameters, including reactor power, steam pressure and feedwater-flow rate.

The second step in the program will be the installation of a forced-recirculation system. Besides providing for an increase in power density,* Harrer feels that forced circulation, since it introduces pumping power as another control variable, will lead to smoother reactor operation and may improve the resonance-instability situation. This latter possibility will be explored by the oscillator technique. The equipment for forced circulation is being designed and purchased and will be installed late this year.

The final step planned is the operation of EBWR as a heavy-water boiling reactor. First of all this means the design of a completely new heavy-water core. The critical experiments for the new core are about to begin. Plans call for the use of urania-thoria fuel elements. In the mean-time work is going ahead to reduce the leakage from the EBWR primary coolant system. The present rate of 88 lb of reactor water per day is too much for heavy-water operation.

When finally installed the heavy-water core will permit a larger power output and will improve the conversion ratio. The combined heavy-water forced-circulation operation is expected to take place sometime in 1958. This mode of operation will represent the ultimate in EBWR performance.

When and if EBWR power is actually going to be increased has not yet been decided. Besides assurances of safety from the oscillator tests such a step would require additional investments in heat-disposal equipment. Harrer indicated that no plans had been made to provide for these modifications. He did, however, observe that on a cool day the present EBWR cooling tower could handle an extra 20 Mw of heat.

* The increase will not be enormous since the flow rate with forced circulation will be 10,000 gal/min while natural circulation already provides a flow of 7,000 gal/min.

---

designed for an operating pressure of 2,000 psig at 636° F, is 9 ft in diameter and can accommodate a reactor core up to 6 ft in diameter and height. The proposed facility would be located at the National Reactor Testing Station in Idaho. The remoteness of the location should allow a more ambitious testing program than is possible at the EBWR location. Finally ARBOR will not be required to generate electric power, thus making its time completely free for basic research on boiling-water-reactor behavior. A primary objective would be the investigation of instability in boiling-water reactors (see p. 56). Because of the factors listed above a more exhaustive study of this and other problems could be done at the ARBOR facility than would be possible at EBWR. Construction of ARBOR is planned to start in the spring of 1958. The reactor should be operating in 1960. (NU, Jan. '57, R8).

Northern States Power Reactor. **Allis-Chalmers has contracted to build a direct-cycle boiling-water reactor for a group of ten mid-western utilities (NU, Mar. '57, R9). The plant will be operated by Northern States Power Co. of Minneapolis. The reactor itself will generate 133 Mw of heat but a superheater using fossil fuel will up the total electrical output to 66 Mw. The steam will go into the superheater at 600 psia and 486°F and come out to the turbine at 540 psia and 1000°F. The reactor power will be adjusted to meet load demand by automatic control of the forced recirculation pumps. Allis Chalmers, builder of the EBWR power generating equipment, plans to complete the $20–$25 million plant by 1962.**

VALLECITOS boiling-water reactor recently dedicated by General Electric. The 5000 kw reactor will test new designs

Item	Annual Charge (10^3)	Contribution to power cost* (mills/kwh)
Capital—$4,628,100 at 15%	694	22
Operation and maintenance	240	8
Fuel costs		
Initial fabrication—$793,100 at 15%	119	4
Initial U rental—$730,000 at 4%	29	1
Annual burnup at 2,000 Mwd/ton	182	6†
Annual fabrication	362	11
TOTAL	1,626	**52 mills/kwh**

* Assuming 3.15×10^7 kwh/yr at 80% plant factor.
† Includes credit for Pu and residual U.

EBWR Power Costs

Initial power costs for this first boiling-water plant are high, but operation at higher power level and with heavy water will tumble costs. Later utility-scale plants look even better

TABLE 1—EBWR Research and Development Costs (10^3)

	Total	Reactor system	Generation system	Fuel and materials	Heat-transfer study
Salaries	726	245	95	262	122
Staff time (*man-years*)	(54.5)	(21.9)	(7.9)	(17.1)	(7.6)
Tech. time (*man-years*)	(40.6)	(9.0)	(4.2)	(17.8)	(4.6)
Special materials (Zr, Nb, boron-stainless steel, etc.)	136			133	3
Materials and supplies—all others	132	12	7	99	14
Irradiation services	92			92	
U processing	15			15	
Computing services	20	15		5	
Chemical analysis	33	0.4	0.2	32.4	
Hot-lab use	27			27	
Subcontracts (development & design)	31			30.8	0.2
Shop fabrication	297	94	2	176	25
Engineering and drafting (ANL shops)	45	30	3	9	3
Services—all others	83	21	9	45	8
Allocated administrative and service costs	1,402	552	192	471	188
TOTALS	3,039	970	308	1,397	364

Because EBWR is the first nuclear power plant in the United States to produce electricity under conditions that would satisfy commercial requirements, special interest centers on the cost of the power it produces. Separate and detailed records of EBWR expenditures have been kept since the project first started in 1954. These provide the basis for a cost analysis that shows a high present cost that can be reduced to more attractive levels by future improvements.

A summary of the cost figures is given in the tables. The costs are intended to apply to the construction and operation of the EBWR as a 5-Mw (electric) light-water, natural-circulation reactor plant. The figures are complete except for shipping charges for the spent fuel elements. Quite reasonably, those capital costs that could be attributed directly to plans for eventually operating the reactor with forced circulation and D_2O moderator-coolant were neglected. (The total amount omitted for these reasons was $220,100.)

Note also that research and development costs (given in Table 1) are not included in determining the capital costs, the philosophy being that these are one-time costs that would not enter in the building of a hypothetical identical sister plant.

Under these ground rules the total cost of power for the EBWR as it is now operating comes to 52 mills/kwh. This figure is complete except for waste disposal costs (which have not yet been evaluated).

However, several factors will operate to reduce this power cost in the future. For one thing, as it stands now, the EBWR could be run at twice its present power. (Some additional investment, of course, would be required—e.g., increased turbogenerator and cooling-tower capacities.) If this were done all costs per kilowatt hour except fuel cost would (roughly) be cut in half. In addition fuel costs were based on a conservative 2,000-Mwd/ton burnup. If the burnup is increased to 10,000-Mwd/ton and the electric power output to 10 Mw the power cost should drop to about 23 mills/kwh.

Further increases in the power of the EBWR will be possible with the addition of forced convection and a heavy-water moderator-coolant. EBWR's designers feel that, with these modifications, the final power cost will be close to 15 mills/kwh.

Further Improvements

This 15-mill/kwh figure is still large compared with the cost of power produced from fossil fuel in this country (about 6 mills/kwh). However, a reactor of the same type, if built today, could do better.

First the EBWR has to do two jobs—it serves as an experimental facility as well as a producer of commercial electric power. This means that the EBWR capital-investment cost includes money for experimental features that would not be present in a single-purpose power reactor. For instance the experimental program calls for operating the reactor with a number of different core configurations. To allow for these changes the designers had to provide extra accessories and a highly flexible core, both of which cost money.

Secondly, even as a power reactor the EBWR is overpriced. The philosophy behind the original design was intentionally conservative. Experience has already shown that many things included in the system "to make sure" could be left out of the next design. For example a forced-convection cooling system had been installed for the control-rod thimbles. The operating temperatures of the thimbles without cooling are lower than expected so that the forced-convection system is not used.

Finally, and probably most important, the capacity of the EBWR as a power reactor is too small to give an optimum investment cost per kilowatt hour. Even after modification for forced convection and heavy water, the EBWR output will be less than 100 Mw (thermal). A reactor in the 500-Mw class or larger could expect to realize a significant decrease in power cost over the EBWR. As a rule of thumb (NUCLEONICS, June '57, p. 74) the investment cost per kilowatt hour varies inversely as the square root of the reactor power. Thus the investment cost per kilowatt could be cut by more than a factor of 2 by building a reactor of this size.

Combining this reduction with all of the other factors we might expect that the final costs for capital investment would contribute something less than 5 mills/kwh. If to this we add a 3-mill/kwh fuel cost (corresponding to a 10,000-Mwd/ton burnup) then competitive power costs do not look so impossible.

* * *

Based upon a presentation by Leonard E. Link of Argonne National Laboratory at the EBWR technical information meeting held recently in Chicago.

TABLE 2—EBWR Capital Costs

Item	*Investment ($10³)*
Buildings	
Office and control building	
General construction	139
Heating, ventilation, air conditioning, plumbing, lighting, electricity, inspection	39
	178
Power plants	
Excavating and backfill	87
Steel shell	288
Shell coatings and thermal insulation	54
Concrete inside shell	177
Inside steel	124
Utilities, air conditioning ducts, painting, etc.	147
Miscellaneous equipment	89
	966
Reactor system	
Foundations	107
Vessel external structure	164
Vessel	202
Vessel internal structure	148
Shielding—total internal & external	398
Control and instrumentation	139
Control rods and drives	182
Boric acid system	58
Fuel handling and storage equipment	68
Feed water system	147
Water purification	60
Steam system	134
Miscellaneous equipment	146
	1,953
Turbogenerator	
Foundations	71
Turbogenerator	408
Condensers and water lines	127
Air dryer system	20
Control	16
	642
Electrical	
Motor controls, switch gear	123
Emergency power	8
Transformers and bus	164
Miscellaneous	68
	363
Outside facilities	
Roads, walks, parking, site preparation	22
Sewers	17
Water lines	11
Cooling tower, basin, water lines, water treatment	56
Steam	35
	141
Architect-Engineering	386
GRAND TOTAL	**$4,629**

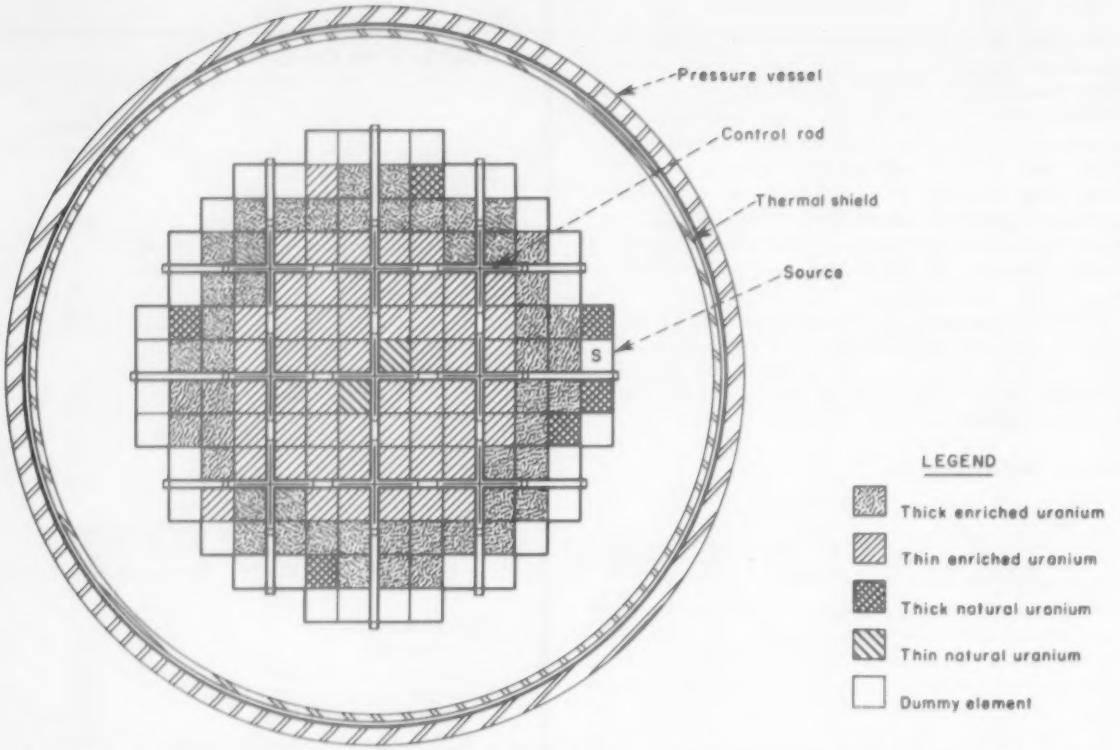


FIG. 1. Final arrangement of the fuel-element assemblies in the EBWR core for full-power operation. Four variations of plate-type elements were used: the plates were thin (0.212 in.) or thick (0.280 in.) and contained natural or enriched (1.44%) uranium

Starting Up EBWR

The leader of the EBWR project tells how they got the reactor up to full power and how it has been behaving since

By JOSEPH W. HARRER
Argonne National Laboratory, Lemont, Illinois

JOE HARRER, author of the accompanying article, puzzles out the next move in startup of EBWR

WORK on the Experimental Boiling Water Reactor (EBWR) began in 1954. The reactor "went critical" on December 1, 1956, and first reached its full power of 20 Mw on December 29, 1956. Since then EBWR has been on several extended runs at full power. (See foldout facing p. 52 for a complete description of EBWR.)

Critical Experiments

Since no critical experiments were run during design work, the month of December was spent in doing critical experiments in the reactor to determine the proper loading for full-power operation.

In the first approach to critical, the core was loaded with a uniform distribution of the four types of elements: thin (0.212 in) and thick (0.280 in.), 1.44% enriched, and thin and thick natural-uranium elements (*1*).

Critical mass was reached between 81 and 87 elements. The 81-element loading had a very high multiplication, probably greater than 10,000. The next loading of 87 ele-

ments completed a symmetrical pattern, and exact criticality, with no rods in the reactor, was not reached.

After the first critical loading, it was evident that more enrichment would be needed. As the loading was increased to 112 assemblies the enriched-to-natural ratio was made higher. Rods were calibrated, keeping the nine rods in a bank. Position accuracy and repeatability was 0.01 in. After a 112-element loading was reached, enrichment was increased by exchanging enriched for natural elements, until $\sim 6\%$ reactivity above cold critical was available.

Styrofoam strips were installed in the water channels to simulate the density reduction of water between room temperature and 488° F water alone, and 488° F water combined with estimated boiling voids density reduction (*2*).

Loading these strips, five to an assembly, took on an average of about 6 min per assembly. A series of critical runs was made during loading intermissions to obtain void-effect data.

The net result of this effort was simply to minimize the reactivity in voids. After full void simulation was completed, estimates of the excess reactivity available led to a selection of the loading of Fig. 1, in which there are 2 thin natural and 4 thick natural, 56 thin enriched and 50 thick enriched elements in the symmetrical loading. The bulk of the thin elements (largest water content) are at the center to keep the effect of voids low. Two additional thick natural enriched elements are placed on either side of the source to increase the source effectiveness or efficiency.

From the Styrofoam experiments, the void coefficient was measured as -0.067% reactivity per percent of voids. The corresponding calculated value had been -0.060%. Again, from the Styrofoam experiments, the reactivity available for burnup was measured to be about 0.8%. The corresponding value observed at full-power operation at 20 Mw, 600 psig, is 1.3%. Combining data from both Styrofoam and full-power operation the reactivity in voids at present, with Xe equilibrium, is 2.2%.

Raising Reactor Power

Before the reactor vessel was closed, foil irradiation at about 100 watts was used to calibrate the ion chambers against flux power in the core. After the system was closed up the approximate power was set by selecting increments of ion-chamber current. Boiling effects were first noted at about 200 kw of estimated flux power. These were evidenced in variations of some 2% in chamber current. The reactor was not preheated in the first power run, and the startup temperature was about 80° F.

Several hours were consumed in reaching the rated 600 psig. Power was held at values below an estimated 1 Mw throughout this time. This turned out to be a fortunate choice, since calibrations of heating rate against chamber current showed that the flux power was probably 2 or 3 times higher than estimated. This error was attributed to reflector water-density changes.

At pressures below about 150 psig, a rather regular cyclic pattern of flux variation occurred with a magnitude of about 20% of the total power and at a period of about 15 to 20 sec (Fig. 2).

Steam lines were next vented and drained. The effect of each such operation was readily apparent on the flux recorder. For this reason, close contact by phone, and through the paging system, was maintained. The communication system was a vital plant component throughout this stage of operation. As each line was opened, the flux would fall, then tend to return to the original value as equilibrium was reestablished. Disturbances were some 10 to 20% in magnitude and 10 to 15 sec in duration.

As a rule of thumb, no rods were dropped, unless the flux rose some 20% above the starting equilibrium value. When this condition was exceeded, one rod was dropped to cut back power. The rod was then raised again and equilibrium power reestablished. As the operating group became aware of the effect of each plant operation, the startup procedure was improved.

Experience to date seems to indicate that it is probably safe enough to start the reactor with room-temperature water. On the other hand, for routine operation, preheating to a higher pressure gives a much more predictable set of startup observations, probably because circulation is established more quickly and the 15-sec cyclic variations are lower in magnitude. (Compare Fig. 2 with Fig. 3.)

An experiment was run in which the reactor water level was raised about 1 ft over the upper core shroud. As heating progressed at pressures below 100 psig, the water was allowed to boil off. Some increase in magnitude of the cyclic variation in flux was observed as the level of water fell below the upper shroud. It decreased when the level was subsequently raised. This test seemed to indicate that water surging over the shroud and irregular downcomer water flow account for the cyclic variations.

When properly recognized, the effect on flux of the inception of boiling is not disturbing and probably will not be a major consideration in future operation.

Steam-Plant Check

The entire steam plant had been checked out prior to boiling the reactor, using 190-psig steam from the Laboratory supply. This work went on while the core loading was being tested. This process served, among other things, as a cleaning process for steam and water systems. The condensate was run to drains.

The importance of this step should not be minimized, because a shake-down period is necessary in any power plant. In the boiling-reactor plant, it would be difficult, if not hazardous, to go through this same process with radioactive reactor steam.

The steam, water and electrical portions of the plant were run in this way, with the generator putting out about 750 kw for a period of several hours. After this checkout, the final connections for steam between the reactor and steam drum were made, and the feedwater system was connected to the reactor. The reactor vessel was scrubbed and washed with high-purity water.

Approach to Full Power

The reactor power was raised until about 10,000 lb/hr of 600-psig steam was passing directly to the desuperheater in the condenser through the turbine bypass valve. Feedwater flow and steam flow were carefully balanced by manual control. Both were then put on automatic control, the controlled parameters, rate of change of both pressure and water level, being held near zero.

The functioning of these automatic control systems had been thoroughly checked by preoperational tests and were determined to be reliable. Most important was the fact

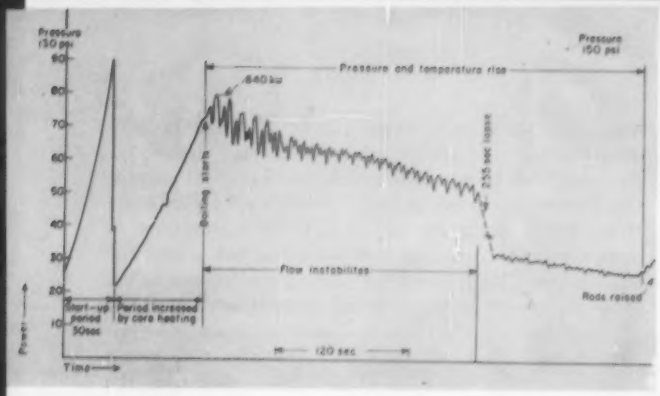


FIG. 2. Strip chart showing reactor power as a function of time for low-pressure startup. Power oscillations are evidence of reactor instability at low pressure (compare with Fig. 3)

that they were thoroughly understood by the operating crew. Since these controls allowed focusing attention on more important parameters, such as flux variation, the automatic systems were used immediately.

Power was raised in steps of about 10,000 lb/hr, until steam flow reached 60,000 lb/hr. A careful check on rod motion showed that the target value of about 2% reactivity in voids probably would be met. A high-frequency response recorder was used to watch for possible "chugs" or a sudden large fall or rise in flux signal. This supplemented the operational flux recorder, which had a full-scale pen travel of about 4 sec.

When 60,000 lb/hr was reached on the steam-flow meter, the reactor should have been at 20 Mw. There was, however, no correlation between water-flow reading and steam flow. Steam samples were taken to check for moisture. It was found that the steam was very high in moisture content. Apparently the separated moisture in the steam dryer was not returning to the reactor by gravity as expected. Instead, due to the low pressure in the steam-dryer drum (resulting from the steam flow through the pipe in the reactor shield), the water was flowing upward into the dryer and mixing with the steam.

To correct this condition the return line was closed by installing a valve and a steam-water trap was installed at the drum with a blow-down to the condenser. A design error was also found in the steam-flow orifice, so that the instrument had to be readjusted.

After these changes, the plant was restarted and all meter readings were found to check. Full power of 60,000 lb/hr was reached, the turbine was warmed up, and the generator synchronized and loaded. Adjustments were found necessary to the generator protective relays, and the generator governor was reworked to give better speed control.

Running at Full Power

A test run at full power was then started. Overflux trips were set to about 120% power. The steam power back-pressure regulator was set to open at about 625 psig. Overpressure shutdown interlock was set at 625 psig. The run was continued for 7 days during which time several system safety tests were run.

Even though at full power and 600 psig the flux variation was less than 4%, there was some chance that a sudden uncontrolled surge in feedwater could send the reactor into unstable operation. To test this possibility, the feedwater was run to zero, then up to 90,000 lb/hr in about 30 sec, the full speed of the control valve. The flux followed the variation, falling to about 65% of power at zero feed and rising to about 120% power as the feed rate was raised. The time delay between the start of a change in feedwater flow and when a change was noticed in flux was about 10 sec. This test established the fact that unstable operation would not result from mismanagement of feedwater.

A similar test was made with steam flow in which the flow was lowered to about 10,000 lb/hr and raised to some 80,000 lb/hr. Here the flux responded by rising rapidly as the steam flow was cut down and falling rapidly as the flow was raised. No time delay was observed, but the instrumentation was not adequate to produce quantitative results. Again, it was demonstrated that no unstable operation could be effected in this manner.

Setting the overflux trips at 120% power provided adequate protection against steam- or water-control malfunction. One should, of course, observe further that if the trips are set at this overflux value in a central-station power plant, the failure of feedwater or steam-flow control could result in an overflux shutdown. Partial or selective reactivity reduction to improve plant reliability should be considered for such plants.

Burst-Slug Detection

An important phase in early operation was the concern about fuel-element failure. The proposed method was to monitor the gamma activity of the gas at the condenser air ejector. Evaluation of the method was undertaken

Critical Experiments—in the Reactor

EBWR designers followed the unorthodox procedure of doing the critical experiments for the reactor in the reactor itself after it had been built. The critical experiments were successful—a striking feature was the use of Styrofoam to simulate voids. Nevertheless the designers now feel that they wouldn't do it this way again.

The core design was based entirely on the results of two-group neutron-diffusion calculations. No critical experiments were run during the design. The fuel was fabricated so as to provide enough flexibility to cover the estimated inaccuracy in the physics calculations (two different thicknesses and both 1.44% and natural enrichments). After the reactor was built the predicted loading was checked experimentally at zero power by shifting fuel around in the open vessel of the reactor. The experiments showed that the two-group calculations had underestimated the loading by 3.39%. Since the uncertainty in the calculations had previously been estimated to be ±3.67%, the agreement is satisfactory. When coupled with a generous burnup allowance, the underestimate was large enough, however, to require that practically all the fuel elements (95%) used be of the slightly enriched type.

Void Simulation with Styrofoam

The main objective of the critical experiments was to determine the optimum loading for operation at full power and pressure. Water-density changes with temperature and steam voids formed during boiling cause significant differences in reactivity between full-power and zero-power operation. Since critical experiments must be done at zero power, there was a problem of how to mock up the temperature and steam-void effects to represent the full-power condition.

After considering several possibilities the EBWR designers hit upon the idea of inserting strips of Styrofoam into the core coolant passages to simulate changes in water density and the presence of steam voids. Styrofoam is a commercially available

using a 2 × 2-in. NaI crystal and a photomultiplier feeding a 256-channel pulse-height analyzer.

A broad Compton plateau was found from 0 to about 6 Mev, due to N^{16} activity. A small peak or hump was present at 0.5 Mev, due to Xe^{135} and Xe^{138} activities. The magnitude of the Compton plateau followed reactor power.

Immediately upon reaching 20 Mw in the reactor it was apparent that Xe gas was present at the air ejector from the gamma-spectrum analysis. Gas and water samples were taken and analyzed. This analysis showed that 284 μc/min of Cs^{138}, 18 μc/min of Xe^{135} and 6 μc/min of Kr^{85} were released in the air-ejector gas. There were also traces of fission products in the water. Both the activity in the gas and fission products in the water have been nearly constant during operation for several months.

This activity could be accounted for by 40 mg of fuel alloy. Since the activity remains constant, it is assumed that the surfaces of the fuel plates were contaminated. If there were a leak the hole would be about 10^{-4} cm square.

The presence of this small amount of xenon has helped to establish the method of detection as practical. A continuously monitoring system is being installed, using a 1 × 1-in. NaI (Th) crystal and a pair of counting-rate circuits. One measures the Compton plateau, the other the 0.5-Mev Xe; the difference is used to set off an alarm.

Shutdown Procedure

The design of the electrical control system is being reviewed in the light of what is needed to simplify shutdown operation during the long-term routine runs. One change has been made. When the reactor is shut down for any reason, both the steam line to the turbine and the feedwater valve are closed automatically. This reduces the possibility that slow operator reaction can result in leaving the system open and permit a temperature stress at the reactor pressure vessel, due to blowdown of steam.

The feedwater pump is interlocked so that upon loss of hot-well level the motor is stopped. To do this, a float switch was installed at the hot well. It has been found that a sudden change in steam flow, such as reactor shutdown, operates this interlock unnecessarily.

The pump will not build up pressure unless outlet valves are closed. The recirculation of water through the air-ejector coolers has an automatic feature which opens the line at zero flow. The pump therefore cannot be started from the control room unless an operator is sent into the plant to close the outlet valves. This system is being revised to permit restarting the pump, and the interlock will probably be time-delayed to give the float switch time to reclose after the steam flow is changed suddenly.

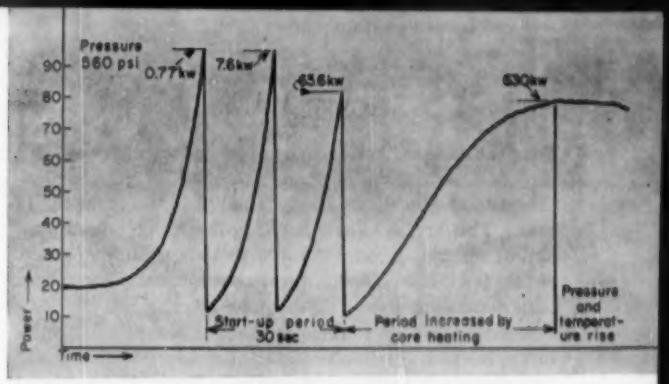


FIG. 3. Strip chart showing reactor power as a function of time for high-pressure startup. Absence of power oscillations (compare with Fig. 2) demonstrates high-pressure stability

Auxiliary Systems

Containment-shell problems. Characteristically many of our major headaches in building the reactor stemmed from minor construction details. A good example was the problems encountered in making the reactor-containment shell leakproof. To provide adequate protection in case of an accident we had guaranteed that the leakage of air from the containment shell would be less than 1,000 ft^3/day at an internal pressure of 15 psig.

The containment shell was built and tested prior to installation of the concrete and equipment. The shell openings for condenser circulating water, air ducts, mechanical operators for boron injection valves, the freight door, the air locks (of which there are two: the main air lock and the smaller emergency air lock) and electrical cable penetrations were omitted from the initial test.

The original test on the shell alone was successful. But when the building was finally completed for operation, obtaining a second successful leakage test was quite another problem. Even though some precautions were used to make what appeared to be tight joints and secure gasketing, the main shell penetrations listed above leaked badly.

It was not expedient to continue pressurizing the building just to find leaks. A 3-day test at 15 psig was run in which all the leaks that could be found were inventoried.

---

material that is manufactured by foaming melted polystyrene. It has a density of only 0.03 gm/cm³, which makes it quite suitable for making voids in water. Its nuclear properties were investigated and found to be unobjectionable. Special sanding techniques were evolved to finish the styrofoam strips to required dimensions with sufficient accuracy. Heated circular "cookie cutters" were used to cut holes simulating non-voids.

The Styrofoam was used to determine the reactivity effects as follows: The experimenters first calculated the density change and void volume expected at design pressure, temperature and power. They then inserted corresponding amounts of Styrofoam into the reactor core and noted the change in reactivity. Reactivity measurements were made for the temperature effect alone and for the boiling and temperature effects combined. One complaint against the Styrofoam was that it tended to soak up water, thus making its void volume uncertain. However, the effect was small enough so that, after applying suitable corrections, the EBWR physicists were able to get sufficient accuracy for their reactivity measurements. The Styrofoam technique was successfully used to arrive at a final loading that minimized steam-void reactivity and provided the proper excess reactivity for burnup.

Never Again

After all was said and done Joseph Harrer, project supervisor for EBWR, disclosed that next time things would be done differently. There will be no more critical experiments in situ. Plans are to back up the new EBWR heavy-water core design with the standard kinds of critical experiments before it is built. Although the unorthodox procedure did work out all right, Harrer feels that it has serious disadvantages. First, since the critical experiments are tying up a very expensive facility, there is the pressure of time. Only three weeks were allocated for these investigations in EBWR. During this time the experimenters worked double shifts but still did not get as much information as they would like to have had. Second, the extra investment in fuel required to cover the inaccuracy in the physics calculations would go a long way in paying for more precise determinations by ordinary critical experiments.

Then the various devices such as the air-lock doors and the vent and intake dampers were isolated in units so that they could be pressurized individually and tested for tightness. This arrangement should probably have been part of the original design. (Considerable saving in time would be effected if individual unit tests were provided for, rather than depending upon field-test methods.)

A major leakage problem existed at the cable troughs through which 300 multiconductor cables penetrated the shell for control and power purposes. Each cable had been tested individually to ensure that there was no leakage along the cable itself. If there was leakage the ends were closed with solder lugs and a solid wrapping of tape used to make the cable itself leaktight. All stranded conductors were treated in this manner.

However, where the troughs penetrated the shell proper, a real problem existed. The trough is 2 ft wide and presents a 2 × 1-ft area for cable egress. The total length of the trough was about 6 ft, penetrating the 2-ft concrete liner support inside the lower shell region. The design called for filling the troughs with Chico cement. Chico cement is not itself leaktight; nor does it seal tightly to the cable or steel. We were aware of this problem and intended to fill the trough at the inside with Novoid compound, which, under pressure from the building, would seal the Chico by penetrating any tiny opening along a cable or side of the trough.

The idea probably would have worked, except for one minor difficulty. The trough seams were not seal-welded shut; instead by some oversight only a simple seam weld had been run. Thus air bypassed the Novoid compound, resulting in extremely high leakage. Since the troughs were then completely encased in the concrete and could no longer be welded shut, it was necessary to try makeshift methods to cork the cables on the outside of the shell.

Several weeks of experimentation led to building up the troughs about 8 in. at the outside and finally filling this with a two-part epoxy resin that sealed tightly against cables and troughs and effectively "corked" the opening. A successful test was then made that showed the leakage was actually less than the required minimum.

Control-rod operation. EBWR is the first reactor to use the pressure-breakdown ring seal on rod drives. Although the method has been thoroughly tested, the experience with nine such rods in an operating reactor is of interest.

The average radial clearance in the nylon bushing above the seal was 0.0017 in. It was found that, after several weeks, iron dust accumulated at this point. Rods therefore stuck at zero pressure owing to binding in this bushing. The clearance was increased to 0.0076 in., and this apparently has eliminated the trouble.

Seal leakage is about 200 cm³/min. The thimble extending through the lower shield plug runs at about 150° F during operation without cooling. Injection of water at the rod thimble causes a noticeable drop in the lower vessel head temperature so that it is considered unwise to use this system. Because of the low leakage the heat does not travel downward and the forced cooling probably will be abandoned entirely.

Ion-exchanger system. Continuous cleanup of the water through the mixed-bed ion exchanger at a rate of 8–9 gal/min has maintained the water at 10^6 ohm-cm resistivity.

Steam and turbine system. Operation to date has not been enough to determine if any contamination of the turbine or steam system will occur. An incidental difficulty threw some light on this subject. A mechanical difficulty with the main steam throttle valve required opening it and replacing the valve extension shaft. Operations on this valve had caused the shaft to be stressed beyond the yield point so that it was elongated ⅜ in.

In this operation, the Kanigen coating of the valve was examined and found to be in perfect condition. A slight darkening was all that could be observed to compare it with a new surface. No deposited activity could be found.

Liquid-recovery system. The buffer seals with dry air are working as designed. On the other hand, the over-all system, which includes the air drying system (*3*), has met with several practical difficulties. One major difficulty stemmed from the fact that at 20-Mw operation, as already noted, the air-ejector gas contained Cs^{138}, Xe^{135} and Kr^{85} activities.

Recirculation of this gas to the dry-air buffer seals raised the building-air-activity level to a point considered undesirable, although not dangerous. The main activity carried by the building air was Cs^{138}. To correct this condition, the gas is discharged at the stack.

A second difficulty was found in the air-drying-system control itself. The two design pressures of 6 in. water below and 6 in. water above atmosphere cannot both be controlled automatically with the system as designed. At present, the positive 6-in. pressure is controlled manually, providing a reference for control of the negative 6-in. value.

A third problem stems from the fact that the 1-psig gland seal steam contains radioactive gases, just as the main steam system does. This gas cannot be used for the buffer seals without raising the building air activity, even though this is again very small in quantity.

This system is therefore open to a complete review, both from a basic and from a functional design standpoint.

Decomposition gases. The radiolytic gas content of the steam has been measured. It is 55 cm³/l of condensate. The composition of the gas is 30% O_2; 66% H_2; and 4% inert.

System-water leakage rate. At the moment the loss of water from the system is much too high to meet D_2O operating requirements. The current outleakage rate is estimated to be 88 lb/day; 1 lb/day has been set as the design target for the D_2O loss. About 60 of the 88 lb/day leaves the reactor through the air-ejection system as dissociated water. This will be corrected by the addition of a recombiner now under design. Most of the remaining loss is accounted for by 200 or so leaky valves scattered throughout the reactor system. The inleakage is in better shape. It is estimated to be 1 lb/day compared with the desired design specification of ½ lb/day.

* * *

Many observations and data contained here were furnished by S. A. Bernsen, R. D. Cook, C. V. Hall, A. S. Jameson, W. J. Kann, W. C. Lipinski, J. A. Thie and E. A. Wimunc.

BIBLIOGRAPHY

1. J. Thie. EBWR physics experiments. ANL-5711 (1957)
2. J. A. DeShong, Jr. Styrofoam simulation of boiling and temperature effects in the EBWR cold critical experiments. ANL-5697 (1957)
3. E. L. Young. Air-drying system for EBWR turbine seals. NUCLEONICS **15**, No. 4, 105 (1957)

Gamma-Ray Streaming Through a Duct

By DAVID G. CHAPPELL
Knolls Atomic Power Laboratory, General Electric Co., Schenectady, New York

PRACTICAL DESIGN of biological shields for radiation sources often involves accounting for the gamma flux that streams through a cylindrical duct that penetrates the shield.

This nomogram permits rapid determination of the geometrical attenuation of the gamma flux streaming through the duct from an emitting surface upon which the duct abuts perpendicularly. Scattering effects are not accounted for.

The formula for the attenuation* is

$$A = \frac{K}{4}\left(\frac{D}{L}\right)^2$$

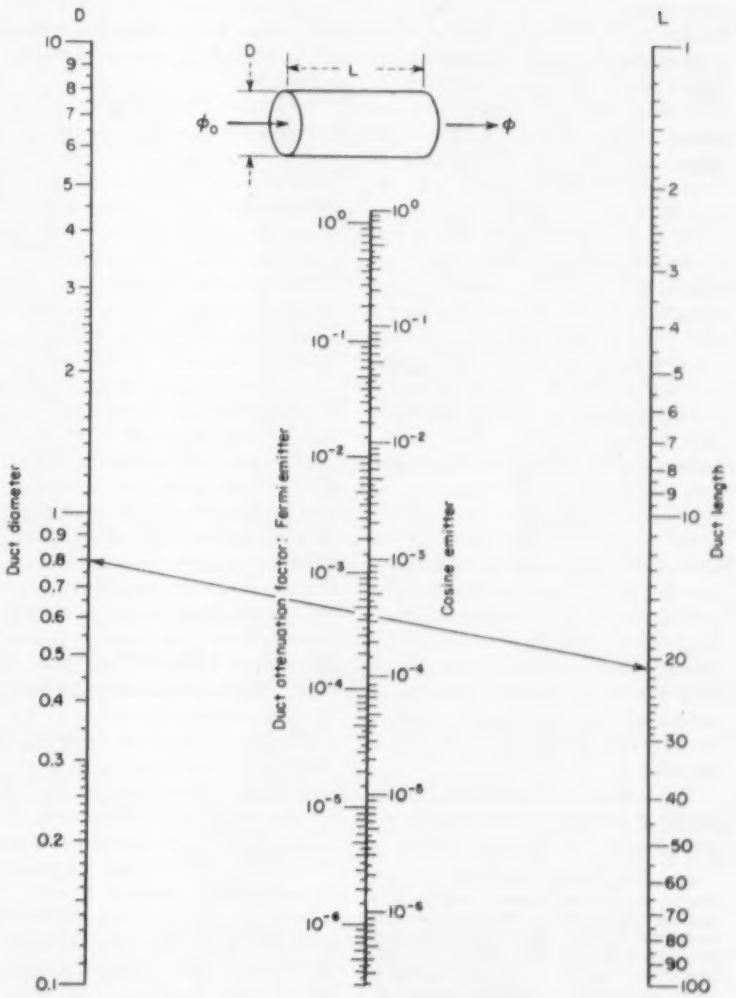
where K is ½, 1, 1.268 for a spherical, cosine and Fermi emitter, respectively; D is the diameter of the duct; and L is the duct length in identical units. The formula is valid if $L \gg D$, i.e., long, thin, straight cylindrical ducts for which $(D/2)^2$ is negligible compared with L^2.

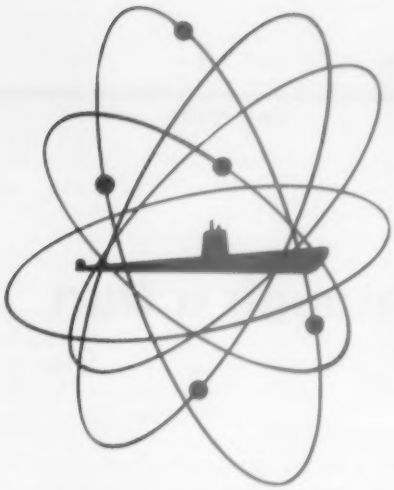
Example: 0.8-in.-diameter duct penetrates 21-in.-thick shield and abuts perpendicularly onto a cosine emitting surface. As shown, the nomogram gives $A = 3.5 \times 10^{-4}$ for a cosine emitter, 4.6×10^{-4} for a Fermi emitter. Attenuation for a spherical emitter is half that of the cosine emitter, or 1.8×10^{-4}.

* * *

I wish to acknowledge the assistance of Miss Joyce Berger, who drew the nomogram. Knolls Atomic Power Laboratory is operated by the General Electric Co. for the U. S. Atomic Energy Commission under contract No. W-31-109 Eng. 52.

* "Reactor Shielding Design Manual," T. Rockwell III, editor, p. 290 (McGraw-Hill Book Co., New York, 1956).





Nuclear Navy Paces U. S. Atomic Industry

75–100 reactors over next 8 years leads industry in history's biggest reconversion program

By JOHN E. KENTON, *News Editor, NUCLEONICS*

IN THE SPACIOUS, memento-filled Pentagon office of the Chief of Naval Operations, Admiral Arleigh A. Burke keeps on a large table next to his desk a huge flat book. In it are outlined the two master plans for the Navy's long-range future fleet effective. One, revised each year, covers the shipbuilding programs of the next five years. The other, less firmly fixed, extends 25 years (average life of a ship is 20–25) and tries to cope with the question, where is the Navy going? Right now the book contains the blueprint and the timetable for what is surely the most gigantic technical revolution ever carried out by deliberate plan over so short a period of time: the complete conversion of the U. S. combat fleet to nuclear propulsion. As Admiral Burke likes to point out, it took 400 years for navies to shift from spears to gunpowder, 75 years from sail to steam, but less than 12 years from the unlocking of the atom to nuclear power. It now looks as though the actual transformation of the fleet may be close to being half carried out in a mere 18 years.* It is already a year since the Navy laid down its last non-nuclear submarine; and the sixth *Forrestal*-class supercarrier will be, if Congress approves Navy plans, the last oil-burning U. S. flattop.

This has not yet registered in the minds of people not immediately concerned with the program nearly as widely as have the stories of *Nautilus* and her sensational success. Nor is it generally appreciated that the Navy has already made the epoch-making decision to convert to nuclear power for all fighting ships, surface as well as submersible.

What such a vast program means to a civilian atomic energy equipment industry struggling to be born is little short of staggering, particularly with attention having been primarily focused during the past two years on the great Gore bill debate and the question of civilian reactor acceleration. Meanwhile, the massive part of the present Navy program has, in a manner of speaking, sneaked up on the scene. The present Navy program, including the fiscal '58 shipbuilding program now before Congress, involves 30 seagoing reactors plus six land-based prototypes, all to be completed and operating by 1961; and no less than 40 more reactors are contemplated *for carriers alone* over the succeeding five years to 1966. And this is without counting the spare reactor vessels, spare vessel closure heads, spare canned rotor pumps—spares of all items of hardware, no matter how costly, that might require replacement. For nuclear propulsion is no exception to the Navy's standard operating procedure of providing spare parts of everything at dockside. It would be inconceivable for a Navy unit to be immobilized in port for the two years that it takes to fabricate, for example, a replacement reactor vessel. The volume of work on Navy contracts is indeed so great that, far from a dearth of business, some industry people see some danger of conflict between naval and civilian orders for the still-limited manufacturing facilities.

From the inception of the naval propulsion program through June 30, 1956, AEC alone—exclusive of the Navy—has spent $273.3-million on it, $182.5-million on research and development, $90.8-million on construction. The fiscal '56 outlay of $50.7-million was a 28% increase over the $39.7-million spent in fiscal '55. The carrier program alone will raise this to a $350-million/yr business by 1958 or 1959 for a total of at least $500-million. The Navy for its part has spent a cool $1.5-billion for nuclear ships from *Nautilus* through the 1958 program.

Over and above this direct contribution the naval program is making to the atomic industry are even greater indirect contributions. It was the Navy program, for example, that crash-developed the technology of zirconium and made it a usable material for civilian reactors. How many other examples might be cited will probably not be known as long as *Nautilus* remains classified. And it should not be forgotten that *Nautilus* and her Idaho prototype contain the first reactors in the world to produce power in usable quantities. Indeed, the first large U. S. civilian power station, PWR, originated as the CVR project (Carrier Vessel Reactor) started by Westinghouse for the Navy in 1952 and deferred by the latter in 1953.

Today's vast program is being carried out by a joint Navy–Atomic Energy Commission team. The word "joint" does not perhaps indicate sufficiently how close is the collaboration, for the hard core of key officials wears two hats. They belong both to AEC's Naval Reactors Branch and to the Navy's "Code 1500," the Bureau of Ships section for nuclear propulsion.

* From April 1948, when the submarine reactor project was formally established at Argonne National Laboratory, to 1966, when the Navy hopes to commission its sixth nuclear aircraft carrier. By that year, other nuclear naval vessels may include, according to NUCLEONICS straight-line projections, some 45 submarines, half a dozen guided-missile cruisers, and the beginning of a flotilla of destroyers.

A Progress Report on the Nuclear Navy

PROJECT DESIG.	SHIP DESIG.	SHIP NAME	YEAR AUTH'D	SHIPBUILDER	WT. † LENGTH	COMPL. ¶ DATE	SUPPLIER: PRIME CONTR.	PRESS. VESSEL	CORE	PRESSURIZER	STEAM GEN.	TURBINE	COST § ($10⁶*)
SUBMARINE													
S1W (STR-I)	land prototype	Arco, Idaho	----	----	----	----	West.	B&W	West.	B&W	FW		
S2W (STR-II)	SSN-571	NAUTILUS	1952	Electric Boat Groton, Conn.	3,180 319	9/30/54	West.	B&W	West.	B&W	FW	West.	90
S1G (SIR-A)	land prototype	W. Milton, N.Y.	----	----	----	----	GE	CE	GE	‡	B&W		
S2G (SIR-B)	SSN-575	SEAWOLF	1953	Electric Boat	3,260 330	3/30/57	GE	CE	GE	‡	B&W (2)	GE	94
S3W (SFR)	SSN-578	SKATE	1955	Electric Boat	2,190 257	Jan. '58	West.	West.	West.	CE	West.	West.	44-45
S4W (SFR)	SSN-579	SWORDFISH	1955	Portsmouth, N.H., Navy Yard	2,190 257	Oct. '58	West.	West.	West.	CE	West.	West.	44-45
S3W (SFR)	SSN-583	SARGO	1956	Mare Island, Calif., Navy Yard	2,190 257	Oct. '58	West.	B&W	West.	CE	CE	West.	44-45
S4W (SFR)	SSN-584	SEADRAGON	1956	Portsmouth	2,190 257	Jan. '59	West.	B&W	West.	CE	West.	West.	44-45
S5W	SSN-585	SKIPJACK	1956	Electric Boat	2,700 252	Aug. '59	West.	B&W	West.	FW	B&W (2)		59.8
S3G (SAR)	land prototype	W. Milton, N.Y.	----	----	----	----	GE	CE	M&C	B&W	CE (2)		
S4G (SAR)	SSRN-586	TRITON	1956	Electric Boat	5,450	Oct. '59	GE	CE (2)	M&C	B&W	CE (4)		95
S3W	SSGN-587	HALIBUT	1956	Mare Island		July '59	West.	B&W	----	CE	West.	West.	61.1
S5W	SSN-588	SCAMP	1957	Mare Island	2,700 252	1960	West.	B&W		FW	FW (2)	GE	<59
S5W	SSN-589	SCORPION	1957	Electric Boat	2,700 252	1960	West.	B&W		FW	FW (2)	GE	<59
S5W	SSN-590	SCULPIN	1957	Ingalls Shipbuilding Pascagoula, Miss.	2,700 252	1960	West.	B&W		FW	FW (2)	GE	<59
S5W	SSN-591	SHARK	1957	Newport News (Va.) Shipb'ldg & Drydock	2,700 252	1960	West.	B&W		FW	FW (2)	GE	<59
S5W	SSN-592	SNOOK	1957	Ingalls	2,700 252	1960	West.	B&W		FW	FW (2)	GE	<59
S5W	SSN-593	?	1957		2,830 265	1960	West.	B&W		FW	FW (2)		
S1C	land prototype	Windsor, Conn.	----	----		----							
S2C	SSN-?		1958			Dec. '61	CE						
S5W	SSGN-?		1958			Dec. '61							
S5W	SSGN-?		1958			Dec. '61							
S5W	SSGN-?		1958			Dec. '61							
CRUISER													
F1W	CLGN-1	LONG BEACH	1957	Bethlehem Steel, Fore River, Mass.	14,000 700	Oct. '60	West.	CE (2)			FW (8)		87.5
CARRIER													
A1W (LSR)	land prototype	Arco, Idaho	----	----	----	Mid-'58	West.	FW (1) CE (1)	West.	B&W (2)	West. (2) FW (2)		30
A2W	CVAN-1	?	1958*		85,000	1961	West.	FW (4) CE (4)	West.		West. (16) FW (16)	West.	314
DESTROYER													
D1G	land prototype	W. Milton, N.Y.	----	----	----	----	GE						
D2G	DDN-1		?										

* Five more carriers sought by Navy, one each succeeding year, for total of six in service by 1966.
† Upper figure opposite each entry shows displacement tonnage, lower shows length in feet.
‡ No pressurizers in sodium-cooled system.
¶ Date of commissioning for **Nautilus** and **Seawolf**; target dates for completion of others. **Nautilus** was commissioned before starting sea trials on 1/7/55, but was not taken over by Navy until 4/22/55.
§ Best estimate of total cost including Navy's cost for ship and AEC's cost for reactor.

How to Read Nuclear Navy Alphabet Soup

STR—Submarine Thermal Reactor
SIR—Submarine Intermediate Reactor
SAR—Submarine Advanced Reactor
SFR—Submarine Fleet Reactor
SRS—Submarine Reactor, Small
LSR—Large Ship Reactor

In late 1955, a new nomenclature was adopted, consisting of one letter indicating the type of vessel (S for submarine, A for aircraft carrier, F for frigate, D for destroyer); one number indicating the order of construction by the manufacturer of the reactor type; and one letter for the initial of the manufacturer's name (W for Westinghouse, G for General Electric, C for Combustion Engineering). The new reactor designations are shown in the table. Navy vessel designations include:

SSN—Submarine, Nuclear
SSRN—Submarine, Radar, Nuclear
SSGN—Submarine, Guided-missile, Nuclear
CLGN—Cruiser, Light, Guided-missile, Nuclear
CVAN—Carrier Vessel, Attack, Nuclear

Company abbreviations in the table are:

West.—Westinghouse
B&W—Babcock & Wilcox
CE—Combustion Engineering
GE—General Electric
FW—Foster Wheeler
M & C—Metals & Controls

TASK FORCE OF THE FUTURE

Fleet-type sub. These are the first unglamorous, workaday "production" models of nuclear submarines. *Skate*, first of her class, was launched in May and is to be ready to go to sea in January. *Swordfish* is to be launched this month at Portsmouth, N. H., Naval Shipyard, where *Seadragon* is also building; and Mare Island Naval Shipyard near San Francisco is building *Sargo*. Cost of a *Skate*-class submarine is placed at about $44–45-million, half *Nautilus*' estimated cost.

Nautilus and *Seawolf* are both considerably larger than conventional subs; at 3,180 and 3,400 tons surface displacement respectively, they compare with the 1,600–1,900 tons the typical World War II subs displaced. It was to move back in the direction of a more compact—hence more difficult to detect—undersea fighting unit, once the principle of nuclear propulsion had been proven, that Westinghouse was asked to develop a smaller, fleet-sub size reactor (SFR). The medium-size *Skate* class boats, at 2,190 tons, are not as small as the wartime subs, but are about 25 % smaller than *Nautilus*, which they resemble in silhouette (NU, June '57, 25). Their reactors are about half the size of *Nautilus*' and have only about half the output; there have been conflicting statements as to whether or not they will do 20 knots, but they will certainly be slower than *Nautilus*. However the Navy points out they are intended to be an advance over the diesel *Guppy*-type attack sub and an improvement on conventonal submarine technology—not an advance over the bigger *Nautilus*.

The differences in S3W reactor plants going into *Skate* and *Sargo* and the S4W type to equip *Swordfish* and *Seadragon* apparently involve only differences in the shielding. It is understood that one has a conventional sleeve-type shield around the reactor, while in the other it is largely the crew that is shielded from the reactor, with a lead-lined tunnel for passage past the reactor compartment (similar to the crew tunnel in the waist of a B-29).

Radar-picket sub. Only one of this type has been authorized so far, but this electronic watchdog will be by far the world's biggest submarine ever, and the only two-reactor A-sub. *Triton*, now already well along in construction at Electric Boat, will displace a whopping 5,450 tons. She is designed to be fast enough to operate with a fast carrier task force and provide it with radar information. Because of the advanced nature of her reactors (GE's first pressurized water reactor job), a single prototype is being set up at West Milton, adjacent to the *Seawolf* prototype site.

Hunter-killer sub. This midget submarine type will be an anti-sub sub. When the navy sought a third major contractor to enter the naval reactor program, Combustion Engineering Co. was given the assignment in July 1955 of developing the smallest reactor that could be used in a propulsion plant. This will be the smallest of the Navy's five-reactor family, but like the others a pressurized water type. A prototype is to be built at CE's new $15-million Nuclear Engineering and Development Center at Windsor, Conn., (NU, Feb. '57, R1).

These hunter-killers are to be relatively inexpensive, so that they may be produced in quantity. Their small reactors will not give them great speed, but this will not be a disadvantage as their function will be to lie in wait for enemy attack submarines. The first submarine to be powered by so small a reactor was included in the 1958 shipbuilding program now before Congress.

Guided-missile subs. Two conventionally-driven subs, *Tunny* and *Barbero*, have already demonstrated successfully that undersea craft can carry a guided missile (in this case Regulus), and in a matter of minutes surface, bring it out on deck, fire, and disappear below the surface again. Combination of this ability with nuclear endurance creates a weapon that some military men consider the "ultimate."

Accordingly, *Halibut*, a conventional diesel submarine designed specifically to carry guided missiles, was converted before keel-laying to nuclear power. She is now building at Mare Island, and will have an S3W reactor plant. She will cost $61.1-million to build. The Navy of course cannot say how many missiles she will accommodate; however, where *Barbero* carried one Regulus in an improvised tank-like hangar on deck, *Halibut* will store hers below decks in a missile-hangar Secretary Thomas described as "nearly as large as that of an entire submarine of World War I vintage."

So enthusiastic about this type is the Navy that three out of four subs in the 1958 shipbuilding program will be an improved, faster *Halibut*-type.

High-speed attack sub. This is in many ways the most fantastic vessel in the Navy's whole fleet of fantastic new craft. This is a flying submarine that soars underwater as a plane flies through the air, a sub that outmaneuvers destroyers, a boat that travels submerged at speeds that may reach 52 knots—60 mph—according to authoritative speculations.

The project had its inception in the experimental submarine *Albacore*, built to test a new hull design resembling a whale rather than the usual cigar-shaped sub. Every projection has been eliminated save the conning tower, thin like a dorsal fin; virtually no flat deck remains on her rounded back. Power is exerted through a single five-bladed screw (conventional subs as well as *Nautilus*, *Seawolf*, *Skate* are twin-screw); this permits smooth fairing of hull surfaces aft to reduce drag. *Albacore's* speed, like *Nautilus'*, has never been disclosed other than by the cryptic phrase "over 20 knots"; but the Navy has admitted that despite her diesel-and-battery propulsion, *Albacore* is the faster sub, so effective is her tear-drop hull design. Her pilot and copilot are strapped into bucket seats and use airplane-type wheel-and-stick controls to command her movements, which they call hydrobatics. Leather loops like those in subways hang overhead for the benefit of crew members, who perforce become straphangers when she goes into a high-speed turn with a 30° bank.

The idea of marrying this "perfect" hull shape with a nu-

This avoids duplication of staffing and red tape. It goes right to the top, with Rear Admiral Hyman G. Rickover, builder of *Nautilus* and the high priest of nuclear naval propulsion, holding both the titles of chief of NRB at AEC and deputy of BuShips chief for nuclear energy at the Navy. Under him in NRB are about 100 professional and 35 clerical staff.

Objectives

Primary purpose of the naval reactors program is to develop a group of propulsion plants in a wide range of power ratings. At the present time, the program encompasses a family of five reactors, of approximately the following sizes: 1,500 shaft horsepower; 3,000–4,000; 6,000–7,000; 15,000–17,000; and 30,000–40,000 shp. The figures are approximate if only because the development of nuclear propulsion is advancing so rapidly that a project starting out to design, for example, a 4,000 shp plant may end up with one of 7,000 shp. The intent is that these units be usable in any combination—two small or one large, depending on hull characteristics and other external factors. Another specification is to maximize the common features in each reactor size, to simplify the problem of personnel training. This helps explain the Navy's readiness to announce abandonment of sodium-cooled reactors following the initial troubles with *Seawolf*, and to concentrate on pressurized water cooling.

(Another reason was the weight advantage of water-cooled reactors "which require less shielding than any other type we know at the present time, because water absorbs less radioactivity than any of the other coolants," explains BuShips chief Rear Admiral Albert G. Mumma. "Though initially it was felt that the reactor in

clear engine has had naval architects awestruck for the past two–three years. The marriage is already being consummated. *Skipjack*, first of the *Albacore*-hulled A-subs, is rapidly taking shape on the ways at Electric Boat, alongside *Triton*. And six more like her have been authorized.

Five have been contracted for. The sixth—the still-unnamed SSN-593—is being held back to permit further refinements to be made in her hull design and her engineering plant; she is to be assigned to a navy yard in August.

Skipjack's S5W reactor, about the size of *Nautilus'*, is a natural evolution of that pioneer engine, and embodies major improvements in design simplification; in particular, core-changing is expected to be tremendously simplified. Westinghouse designers feel S5W incorporates the best features of STR and SFR, will be the simplest naval reactor yet designed.

Skipjack will cost the Navy $59.9-million, her first five identical sisters less. When she sets out on her trials, it will mark a new epoch in man's going down into the sea in ships.

Cruiser. U. S. S. *Long Beach*, the world's first nuclear-propelled surface ship, will be a guided-missile-armed light cruiser—although the designation of her twin reactors, F1W, recalls the fact that she is the upgraded result of a project that began as a frigate (oversize destroyer). The twin-screw ship will boast no land-based prototype of her own, since she will use the same basic reactor as the carrier—the Large Ship Reactor; so she will share the carrier's Idaho prototype for data needed. The LSR will be adaptable to large naval vessels in either single or multiple installations.

Total cost of the ship is set at $87.5-million. The Fore River yard of Bethlehem Steel's shipbuilding division at Quincy, Mass., will build *Long Beach* (NU, Nov. '56, R2). Keel is to be laid next March. Although she is described as a 31-knot ship, Admiral Burke told NUCLEONICS a speed of 40 knots is not inconceivable.

Carriers. Those who think the 60,000-ton supercarriers *Forrestal* and *Saratoga* are big may well boggle before the 85,000-ton atomic carrier the Navy has just received Congressional approval for. This monster will be driven at 33 knots by a propulsion plant containing eight reactors and 32 heat exchangers powering four screws. Like *Nautilus*, she will have a range of some 75,000 miles between core loadings. She will be the first vessel in which there will be two reactors in tandem driving one propeller shaft. That is why not one but two prototype reactors are being installed in the land-based hull section at the Idaho testing station. The $30-million facility will include all the machinery for one shaft of the carrier, to permit studies on the dynamics of two reactors on one screw. Construction began in April 1956.

Last year Congress authorized expenditure under the 1957 Navy building program of $22-million for advance procurement of long lead-time items. Westinghouse got a $13,-157,000 contract "to design and furnish reactor compartment components" for the carrier—a figure leading to the belief that it covers only eight reactor pressure vessels, not eight complete reactors. Newport News Shipbuilding & Dry Dock Co., as subcontractor to Westinghouse, is working on application of this reactor plant to a carrier hull. This year Congress is appropriating funds for the ship itself. It may be an indication that nuclear power is already becoming conventional in the Navy that Admiral Mumma now sets the cost of the carrier at $314-million, as against the original estimate of $400-million. Of course against this must be set the cost of the first four *Forrestals* $175–$212-million each.

Top Navy strategists are excited about the potentialities of this ship. Among the improvements in carrier construction that nuclear power will permit is emancipation from boiler uptakes and stacks, with consequent freedom to place the "island" anywhere on the flight deck, and to install in it new high-performance radar.

In February, Admiral Burke presented to Congress a plan for rejuvenating the Navy's attack carrier fleet. Burke would have one new nuclear flattop enter service each year from 1961 through 1966.

The jet age makes the larger carriers vital, Burke holds; in addition, the nuclear carrier, having no bunker oil needs, will ship nearly twice the aviation fuel supply of *Forrestal*, doubling the time it can conduct air operations without replenishing avgas. It will have 4,000 ft^2 more flight-deck space and 2,000 ft^2 more hangar-deck space than *Forrestal*. Burke also points out that a nuclear carrier will save $80-million during a ship's 20-year life in fuel oil not burned.

Destroyers. The destroyer project is still furthest from realization because it is the most difficult to achieve—for the same reason as aircraft nuclear propulsion is difficult: weight-to-power ratio must be so low. Destroyers have the most highly-developed power plants in the Navy as far as compactness and light weight are concerned, even more so than submarines. Destroyers' present ratio that nuclear propulsion must try to match is only 60–65 lb/shp, dry. Consequently some kind of technical breakthrough in weight reduction or in shielding may be necessary. This is the job that GE has taken on at the Knolls Atomic Power Lab with its D1G project. Depending on progress, a prototype may be budgeted in fiscal '59 or '60. "In perhaps one or two years scientists might be able to get the pounds per horsepower of nuclear propulsion down to where it can be put on the smaller ships—that's where it would do the most good," Admiral Burke told NUCLEONICS. "They're getting a few pounds off each year. I wouldn't be surprised if in five years it will be feasible to build plants on the same pounds-per-horsepower ratio as present engines."

For the Navy, the stakes are great. Conventional destroyers must refuel at sea every 5–10 days, consequently are also quite weather-dependent. A destroyer reactor will therefore mean a tremendous gain both in operational flexibility and in naval housekeeping. "The destroyer is where we need it [nuclear power] most," Navy Secretary Thomas S. Gates told NUCLEONICS. "That's the real workhorse of the Navy. We'd have put it in there first if we could have."

---

the *Seawolf* would promise a considerable amount of improvement over the reactor in the *Nautilus*, the additional shielding that was required as the state of the art developed negated to a large degree that advantage. . . . The improvement [in shielding weight] since we first started the [shielding research] program may be a factor of two.")

Three companies—Westinghouse, General Electric, and Combustion Engineering—are acting as designers, developers and prime contractors on naval propulsion units, and the work is being carried out at three major development centers: Bettis Atomic Power Division of Westinghouse, Pittsburgh; Knolls Atomic Power Laboratory of GE at Schenectady, N. Y.; and Combustion's Nuclear Development Center at Windsor, Conn.

The A-Fleet Today

The nuclear fleet built, building or authorized as of today—assuming Congress approves the 1958 shipbuilding program—comprises 19 submarines, one cruiser and one carrier (*see cover*) plus a development project for a destroyer-size reactor. Beyond the 1958 building program, the only thing definitely known is that the Navy intends to ask five further carriers, one a year through 1963. In addition, the Navy is working to develop an aircraft reactor for seaplanes, but this is being conducted administratively through AEC's Aircraft Reactors Branch rather than through NRB.

The submarines are of seven types: *Nautilus*, *Seawolf*, fleet-type attack, radar-picket, hunter-killer, guided-missile-launcher, and high-speed attack.

Operational experience with the first two, already in service, is discussed below; the Navy's plans and hopes for the others, and what they will demand by way of reactors, are covered above. A

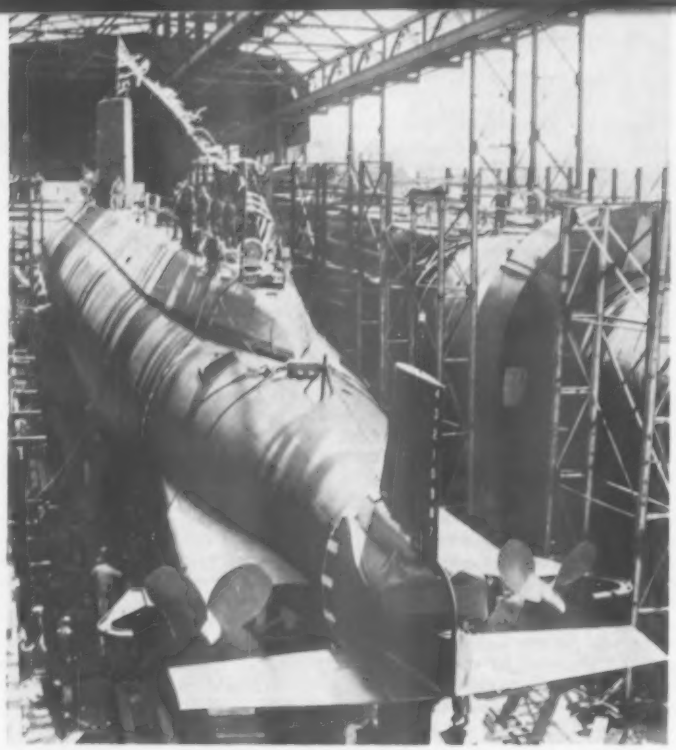
full nuclear task force of such ships is expected to be at sea by 1968.

Nautilus

The story of *Nautilus'* spectacular success is already well known. After having steamed 69,138 statute miles during 5,393 hours underway in 26 months (39,738 of them during 3,065 hours submerged on 859 dives), the pioneer A-sub had her first core removed at her builders', the Electric Boat division of General Dynamics at Groton, Conn. She is now cruising the Pacific on a new core which Westinghouse says is even more efficient than the first and represents a "significant advance." It is said to have cost $2.2-million. Although the Navy has published reams about her reactor-powered galley, washing machines, jukebox, TV and movies (all but the galley unprecedented in a sub), her speed, horsepower and reactor details are of course military secrets. The Navy has said only that she can do "over 20 knots" submerged, and that she has *averaged* 20 knots on a submerged run from Key West to New London, Conn. Occasional driblets of technical data filter through, as when Admiral Burke told Congress the temperature rise across *Nautilus'* reactor is 33° F. But probably quite a few more years will pass, and *Nautilus'* reactor will be obsolete, before a complete, technical description is available.

Nautilus' land-based prototype, the veteran STR Mark I in the Idaho desert at AEC's National Reactor Testing Station, has fulfilled its original functions: to prove nuclear power feasible for naval vessels, to find and eliminate design deficiencies in *Nautilus'* plant, and to train her crew. Now redesignated NRF for Naval Reactor Facility, the unit is being used as a test facility to study new developments in the technology, design and operation of improved pressurized-water plants. It also got a new core after the first had operated 2½ years. The new core gave a stunning demonstration of the endurance of nuclear-powered ships by running non-stop for 66 days, long enough to have gone twice around the world.

Although most celebrated for her endurance, *Nautilus* has performed brilliantly on maneuvers and is forcing —and helping—Navy tacticians to rewrite the book. "Perhaps the most significant aspect of the performance of *Nautilus* has been her reliability," former Navy secretary Charles S. Thomas has said. "In 50,000 miles her engineering plant has not experienced a single disabling casualty."



U IS FOR URANIUM IN THIS U-BOAT. Stern view of Navy's third nuclear sub, Skate, taken an hour before her launching May 16, shows twin screws, stern diving planes, rudder, and, canvas-covered between props, her after torpedo tubes. To right, Skipjack is building

Nautilus' cost may be harder to determine than her speed—even the Navy itself admits it may never know just how much the big sub cost. $55-million was the figure used in the press when she first went to sea Jan. 17, 1955. But since, Sec. Thomas has told Congress the "original cost" was about $90-million. What makes it difficult is that one must distinguish whether one is counting total amount spent from start of a project to commissioning of a ship, including land prototype, metallurgical research, etc., or whether one is just totaling price-tags on each tangible item in a ship.

What is certain is that costs are already slowly starting downwards. Admiral Rickover thinks they will continue to fall until an A-sub costs only $10-million more than a diesel boat. Admiral Mumma told Congress this year that "the intensive development of nuclear power for ships has cut the price of their atomic power more than in half. . . . Comparatively it costs about three times as much now for nuclear power, fuel, than it does for ordinary fuel, on a straight mile-per-mile basis. The reason is, first, this is a brand-new technology; it is not fully developed. We also have the necessity for very careful single-time processing instead of mass production techniques. So that we expect in a few years we will have the fuel costs where they are exactly identical. We hope as a matter of fact that in 10 years nuclear power will be cheaper."

Seawolf

The Navy's second nuclear sub has been at sea almost six months after long delays due to corrosion leakage in the steam generators and superheaters caused by high gamma activity from the primary coolant, sodium.

Admiral Burke told Congress that with her superheaters bypassed, *Seawolf* is operational but limited to 80% of designed horsepower rating and 90% of designed maximum speed. Admiral Rickover has said "it is probable that *Seawolf's* sodium-cooled plant will have to be replaced with a *Nautilus*-type pressurized water plant." However Navy spokesmen say no final decision has been reached, and in any case it is unlikely that such a change would be made until *Seawolf* has exhausted her present core. "Even in its damaged state," says Admiral Mumma, "*Seawolf* is a better submarine than any of our conventional-powered submarines."

AEC and Navy officials have repeatedly pointed out that when the first two A-subs' plant designs were first considered, sodium appeared to offer several advantages over water as a coolant including the promise of reducing weight and improving plant efficiency; and that the two plants were undertaken simultaneously because the need to develop a nuclear-powered submarine was great and it was not known then that either type would work. However, "even with satisfactory heat exchangers, the liquid sodium system does not prove to have the weight and performance advantages for shipboard use that were originally hoped for it," said AEC Commissioner W. F. Libby. "The reason lies in the high gamma ray intensities of the liquid sodium coolant and the difficulties which result from even minor leakage." So the Navy has abandoned sodium cooling for shipboard use, at the same time pointing out that the project has already paid off in data obtained applicable to aircraft nuclear and civilian power.

Seawolf's own prototype plant was also subject to corrosion leak trouble, and has now been deactivated (NU, April '57, 24).

Neutrons in the Navy

Some of the greatest advantages of nuclear power are sometimes overlooked, perhaps because of their very obviousness. Thus it is not merely the great endurance that nuclear power confers on a vessel that is the cause for rejoicing among the Navy's strategists. Even more important is the fact—inconceivable before Fermi—that a ship's cruising speed equals her top speed. Where a ship used to operate at full power from 20% to as little as 1% of the time (because fossil fuel consumption increases as the cube of the speed), a reactor-powered ship can operate at full power 80, or 85, or 90% of the time. Submerged speed of a conventional World War II sub was 2–3 knots under ordinary conditions, and it could travel for only one hour at full speed of 8–9 knots. A conventional steam plant in a surface ship rarely ever ran more than 12 hrs consecutively at full speed in wartime. *Nautilus'* Idaho prototype ran 1,600 hrs non-stop *at full speed.* All the implications of what this will mean to fleet operations takes an effort of the imagination to grasp.

But it also imposes a new condition. If ships are to operate at top power 90 instead of 20% of the time, obviously conventional components—not only in non-nuclear portions of the propulsion plant, but throughout the entire ship—must be able to meet the new burden. Filters, strainers, burners, pumps, valves, bearings—all will have to be improved if they are to stand the strain. This is one of the greatest challenges facing industry. Admiral Rickover has already pointed out that the reliability of conventional components in reactor plants is one of the softest spots in the development of nuclear propulsion (NU, April '57, 78).

Besides the full utilization of top speed, nuclear power holds out other technical and economic advantages to the Navy. As Admiral Mumma listed them for NUCLEONICS, atomic energy cuts forever the apron-strings that tied a ship to within a specified distance of a specified point—its fuel depot. It clears ships' topside of the clutter of uptakes and intakes, space that can now be properly utilized for improved radar and weapon equipment, giving the ship greater resistance to atomic warfare. It also makes better internal disposition possible. Elimination of fuel bunkers means a major reduction of fire hazard. Vulnerability below the water-line is reduced, ability to resist battle damage of all kinds is heightened; the new machinery is more self-contained. Reactor shielding helps act as armorplate against actual physically-inflicted damage, so that a reactor is "a pretty damn rugged, robust piece of equipment"; and furthermore, its vitals are further in from the ship's skin.

"All these things are now sufficient, we consider," Admiral Mumma concludes, "to warrant going ahead with nuclear power in spite of the fact it weighs a little more and costs a little more. Weight will soon be competitive, I feel. We think we're damn lucky getting it for a few cents per kwh."

The Navy-Builders

Nuclear ship building poses new problems as well as great opportunities.

For one thing, there is the problem of plant capacity. There are not very many companies equipped to fabricate reactor pressure vessels of 8-in. steel plate; until now Babcock & Wilcox, Combustion Engineering and Foster Wheeler have been just about the only ones. Some industry observers have raised the question whether the immense machine tools needed for such work may not already have been conflictingly scheduled in advance to work on different vessels at the same time. However some help is on the way with the entry of New York Shipbuilding Co. into the pressure-vessel fabricating field (NU, Aug. '56, R9), and others may be expected to follow.

What impact atomic energy has on a shipyard is well told by Carleton Shugg, a former deputy general manager of AEC and since 1950 general manager of Electric Boat, builder of all of the first five prototype A-subs. The primary effect, as he sees it, is on personnel. During World War II EB had 9,000 employees at its main plant including less than a dozen graduate engineers. Today it has 5,800 employees and 350 engineers. Leadership has shifted to younger men—from men over 50 to men under 50 or a good deal younger still.

SKIPJACK'S tear-drop nose will not even be encumbered by bow diving planes, moved up on conning tower. Sketch shows single-screw speedster in her element—submerged

Certain special technical groups, such as shielding engineers and system control men, have had to be added to those usually found in a shipyard design force. "The problem of building up increased technical capacity and effectiveness has applied particularly to the groups engaged on systems engineering, systems control shielding, and stress calculations including special attention to transient conditions," Shugg explains. As an example he cites a pipe stress calculation group of 25 headed by a D.Sc. for methods and a D.Sc. for programming, working on a two-shift operation, in conjunction with two IBM-650 computers.

Full-scale wooden mock-ups have to be used to a much greater extent, especially to prove out accessibility for

(Continued on p. 186)

NEW WAYS IN

Isotopic Analysis of Uranium

By J. E. LOVETT and J. O. ROBERTS
U. S. Atomic Energy Commission, Washington, D. C.

Equally precise but less expensive methods than mass spectrometry are needed for isotopic analysis for U^{235}. Emission spectrography, neutron activation and gamma and alpha counting are promising as alternate approaches

"As a reactor fuel fabricator, how can I be sure that the enriched uranium I received from the AEC has the isotopic composition specified?" . . . "I handle several different enrichments, and one of my men may have mixed some. How can I check this?" . . . "As a processor of irradiated reactor fuels, how can I determine the isotopic composition of my receipts?" . . . "I would like to offer commercial analytical services to the atomic energy field. How does one determine U^{235} content?"

These questions indicate the problem presented in the isotopic analysis of irradiated and unirradiated reactor fuels. The problem is made more difficult by the need for nondestructive analytical techniques. Most work will be in the range of 1–10% U^{235}, but the methods should be useful over the range of 0.6–90% or more.

The AEC Division of Nuclear Materials Management, as one of its primary functions, ensures that records and transfers of such materials as uranium are based on measurement procedures having accuracy and precision appropriate to the dollar value of the material. The standard method of isotopic analysis, utilizing the mass spectrometer, requires an initial outlay of some $50–100,000. To cover the entire range of 0–100% U^{235}, the $100,000 figure is probably a minimum. The Division has for some time recognized the need for less expensive analytical methods, even at the expense of considerable precision, and has encouraged AEC contractors to investigate and develop alternate methods.

Mass Spectrometry

Mass spectrometry, using gaseous UF_6 samples, is capable of high-precision measurements. Isotopic concentrations in the range of 1–2% U^{235} can be measured with a precision of $\pm 0.02\%$ or within $\pm 0.05\%$ for concentrations above 50%. In routine use, precisions of that quality are not maintained but, rather, vary from 0.10% to 0.25%. As many as forty-five routine determinations can be made in 8 hr if all samples have approximately the same concentration.

The gas mass spectrometer has a "memory," and each result is biased toward the previous sample. The memory limits the range in which a given instrument can be used. At Oak Ridge, standards are prepared such that the difference between an unknown and its nearest standard is less than 5% of the standard. Under these conditions, a memory correction is made that approximates 10% of the difference between the standard and the unknown. With fewer standards the memory correction would be larger and less accurate.

The surface-ionization mass spectrometer eliminates the memory effect, and one instrument can be used to cover the entire isotopic range. This instrument uses solid samples plated on a metal ion source. It is not as precise as the gas instrument but is more accurate for absolute measurement of isotopic ratios.

R. F. Smith (Union Carbide Nu-

TABLE 1 — How Methods for Uranium Analysis Compare

METHOD	RANGE	PRECISION	ADVANTAGES	DISADVANTAGES
Mass spectrometer	0 – 100%	±0.02 – 0.05% relative or better	Covers entire range; best available precision	$50,000 – 100,000 initial cost
Emission spectrograph	———	———	Lower initial cost	Precision poor at low concentrations
Echelle	80 – 100% 0.2 – 2.0%	±0.2% ±0.04%	High dispersion	Echelle patterns are not easy to interpret
Jarrell-Ash	80 – 100%	±0.3%	———	———
Eagle	10 – 85%	~±0.4%	———	———
B&L dual grating	0 – 100%		More readily adaptable to photomultipliers	
Neutron activation	Has been studied primarily at <5%	±1% relative	Inexpensive, especially if gamma shielding is already available	Moderate precision; interference from impurities
Selective gamma-ray counting	<2%, >80%	±1.5% relative	———	Low precision
Neutron absorption	Primarily 80 – 100%	±1%	Nondestructive	Requires reactor as neutron source
Zero-power reactor	0 – 100%	Not fully evaluated	Nondestructive	Requires zero-power reactor with accurately instrumented control rod

clear Co.) has estimated the cost of a mass-spectrometer laboratory having one gas instrument. He assumes a 15% down time and that all determinations fall in the range x to $3x$, where x is the minimum isotopic composition encountered. Not including overhead, he estimates $0.56 per determination, where each sample would require at least two determinations. He quotes equipment at $50,000, assuming suitable structure and utilities to be available. Utilities required are air conditioning, 7.5-kva stable power and a water and drain system. Not essential, but useful, are compressed air, oxygen and gas. For health and safety reasons, a hood is required for sample preparation.

Emission Spectroscopy

Despite the problems introduced by U^{236}, the emission spectrograph has many advantages in isotopic analysis. Most commercially available spectrographs are adaptable, the most common adaptation being the use of photomultiplier tubes to replace the photographic plate. This need not be permanently mounted, so that use of the spectrograph for isotopic work does not impair its usefulness in impurity analysis.

The cost, including a custom-built photometer, is approximately one-fifth that of the mass spectrometer. Since most commercial laboratories either have or have uses for a suitable spectrograph, equipment costs for isotopic work would be even less.

Precision is not as good as that attainable with the mass spectrometer but is ample for most work, including process control. With extra effort, results comparable to those with the mass spectrometer should be attainable in all isotopic ranges.

In 1947, D. R. Long and D. D. Smith (Oak Ridge) reported differences in the arc spectra of U^{238} and U^{235}. Several hundred line pairs have been identified and measured, but the pair most commonly employed in isotopic analysis is 4244.372 Å for U^{238} and 4244.124 Å for U^{235}.

Procedures vary according to the instrument available and the isotopic range being measured, with the Jarrell-Ash, the Littrow echelle grating and a 21-ft Eagle being the most common spectrographs.

Brody, Tomkins and Fred (Argonne National Laboratory) use a Baird 3-meter spectrograph fitted with two photomultiplier tubes. With one tube fixed on an unresolved line as an internal standard, the other tube scans the region of the resolved line pair. A ratio recorder is used to trace relative intensities, with peak height minus background being used for analysis. In the second order, resolving power is about 90,000. Using either uranium metal electrodes or an iron hollow cathode loaded with uranium metal, they estimate 20–30 determinations per day. Loading with U_3O_8, some 20–30 min is required to obtain suitable intensities. A single trace in the range of natural uranium (0.7115% U^{235}) to about 5% U^{235} can be analyzed to ±0.13 wt % U^{235}. Above 90% U^{235}, Brody and coworkers measured the U^{235} content to ±0.11% U^{235}.

Kupel and Tichy (General Electric Co.) use a 21-ft Jarrell-Ash to determine isotopic concentrations in the

range of 90% U^{235}. They measure U^{235} by comparing a 4244.37-Å line with a 4261.51-Å line. The isotope U^{234} is obtained by alpha counting, and the U^{235} is obtained by difference, assuming that only the three isotopes are present.

Murphy (Metals and Controls Corp.) analyzes uranium above 90% U^{235} with a Littrow prism spectrograph fitted with a Bausch and Lomb echelle grating. With this system, light is dispersed in two directions, allowing greater dispersion and a greater wavelength coverage. With a densitometer to compare the U^{235} line at 4244.372 Å with a U^{235} line at 4260.33 Å, a precision of ±0.2% U^{235} is obtained under routine conditions of up to twenty analyses per day.

U^{236} problem. The relative importance of various reactions in nuclear piles varies widely with the operating conditions, but as a rough guide, 15% of the U^{235} consumed is converted to U^{236} and does not undergo fission. If the decontaminated fuel is then passed through a cascade, some enrichment may occur, depending on the exact cascade conditions. Since U^{236} is a fair neutron absorber, its presence in reactor fuel is undesirable, and a knowledge of its concentration is of importance. With the mass spectrometer, U^{236} offers no more problem than any other isotope, but with the emission spectrograph, U^{236} not only is difficult to determine but is difficult to separate from U^{235}. Murphy notes, for example, that with about 0.5% U^{236}, his ability to measure 90% U^{235} is impaired. Taking mass-spectrometer values as a standard, his Littrow-echelle combination was capable of an accuracy of ±0.5% U^{235}.

In an alternative approach, Murphy used an Ebert spectrograph. At a concentration of 0.5% U^{236} (in 90% U^{235}) he found a U^{236} line visible but not measurable. At 2.85% U^{236}, the line image was very clear. With a little work to reduce background, he hopes to be able to measure the U^{236} directly.

Wheeler of the Idaho Chemical Processing Plant (Phillips Petroleum) paralleled Murphy's investigation on the Ebert. Using 89% U^{235} with 3.2% U^{236} and 45% U^{235} with 1.6% U^{236}, microphotometer traces clearly showed a usable U^{236} line. His investigation is still in progress, and estimates of precision are not yet available.

Vogel (Mallinckrodt Chemical Works) also employed the Littrow echelle combination to determine isotopic compositions in the range 0.7–1.5% U^{235}. He was able to reproduce his results with an accuracy of ±0.06% U^{235}.

Lee and MacIntyre (Union Carbide Nuclear Co.) use a 21-ft Eagle spectrograph with a 6-in. 15,000-line/in. concave grating to perform isotopic analyses in the range 30–60% U^{235}. As at Argonne, photomultiplier tubes are substituted for the photographic plate. Using a 50-micron entrance slit and a 100-micron exit slit, they found that 74% of the U^{236} light was collected as if it were U^{235}. With the photomultiplier tube in position to collect U^{238} light, 37% of the U^{236} is collected as U^{238}.

On thirty-two samples in the range 10–85% U^{235}, they agreed in all cases within ±0.40% U^{235} with mass-spectrometer values. Above 60% U^{235}, the U^{236} problem became important, and in the range 30–60%, agreement was ±0.10% U^{235} or better. For example, on twenty-five samples at about 37% U^{235}, the largest deviation from the mass-spectrometer value was found to be 0.08%.

At the AEC's New Brunswick Laboratory, preliminary work indicates the feasibility of extending this method of analysis to as low as 0.1 or 0.2% U^{235} by the use of a Bausch and Lomb dual-grating spectrograph. It also appears possible to estimate U^{236} if the present photographic plate can be replaced by a photomultiplier-tube arrangement.

Owen (Goodyear Atomic Corp.) is working on a direct reader to be used with any of several spectrographs. In principle, the spectrum is repeatedly scanned with a single phototube assembly, and the resultant voltage pulses of spectral lines are electronically isolated. Intensity ratios are read directly.

TABLE 2—Uranium Isotopes Having Half-Lives >1 Hr

Nuclide	*Mode of decay*	*Half-life*	*Apparent alpha energy (Mev)*
U^{230}	α	20.8 d	5.85
U^{231}	K	4.3 d	
U^{232}	α	73.6 y	5.31
U^{233}	α	1.62×10^5 y	4.82
U^{234}	α	2.52×10^5 y	4.76
U^{235}	α	7.13×10^8 y	4.58, 4.40, 4.20
U^{236}	α	2.39×10^7 y	4.50
U^{237}	β^-	6.7 d	
U^{238}	α	4.49×10^9 y	4.18

Neutron Activation

When a known amount of uranium is bombarded by thermal neutrons, a measurement of the number of fissions per unit time will indicate the U^{235} concentration. Procedures vary, first as to the source of neutrons, second as to whether or not chemical separations are required, and finally as to the method of counting the fissions that occurred.

Nelson and Aaron (New Brunswick Laboratory) use a radium-beryllium neutron source. After a 10-min exposure, the neutron-induced fissions are measured by counting the gamma activity of the fission products. In the approximate range of natural uranium, precision was ±0.04% U^{235}.

In a modification of the New Brunswick procedure, Beyer, Lewis and Stukenbrocker (National Lead Co.) were able to obtain a precision of ±0.01% U^{235}. They critically evaluated the variables involved, concluding that the most desirable operating conditions are

Sample	500 mg U_3O_8
Container	1½-dram plastic vial
Irradiation	5 min
Counting period	1 min, after 30-sec delay

Both procedures employ a 2.5-curie radium-beryllium source (2.5 gm Ra, 7.5 gm Be) in a block of beryllium about 6 in. on edge. This is surrounded by 20 in. of paraffin, followed by sufficient lead or other shielding to protect personnel.

At National Lead, however, a semiautomatic timer and transport system is used to control irradiation, delay and counting times more accurately than is possible with a stopwatch. Cost of equipment for this procedure is about $30,000, with slightly over half of this going for the neutron source. Running analyses in quadruplicate, one person can complete eighteen analyses per day. Since impurities seriously affect the analysis, sample preparation may be required. National Lead estimates $3 per analysis for pure material and

$6 if the sample must first be extracted with ether.

Voss (Goodyear Atomic Corp.) uses 6 gm of radium in a source of about 7×10^7 neutrons/sec. Depositing 8 mg of uranium on a nickel disk, he irradiates four disks simultaneously. Precisions of $\pm 0.5\%$ U^{235} to $\pm 3.5\%$ U^{235} are obtained routinely over the entire isotopic range.

Since a large part of the cost for a neutron-activation setup is in shielding, the procedure offers advantages to companies already planning gamma-shielded facilities. Ra-Be sources are not the only possible neutron sources, and some others may be much cheaper, albeit less efficient. Neutron activation also offers the possibility of using a neutron beam from a reactor (or critical assembly), but other procedures may be even more attractive, as described later. In any event, neutron activation is presently limited to samples containing less than 5% U^{235}.

Echo and Turk (Phillips Petroleum Co.) irradiate small samples (~1 ml) in the Materials Testing Reactor. They use three different test holes, having 10^{10}, 10^{12}, and 10^{13} n/cm²/sec. After a 4-min irradiation, followed by a 15-sec delay, the delayed neutrons are counted for a 3-min period. The procedure determines the total milligrams of U^{235}, so determination of percentage composition is dependent on a knowledge of the total uranium.

Leddicotte and Brooksbank (ORNL) irradiated uranyl nitrate solutions for 100 hr at 6.5×10^{11} n/cm²/sec. After 1 day of decay, the Ba^{140} and Np^{239} were separated by conventional carrier techniques. By comparison with a standard, irradiated at the same time, U^{235} was determined with an accuracy of $\pm 0.015\%$ U^{235} in the range of natural uranium.

Nondestructive tests for fuel elements. In the fabrication of reactor fuel elements, including subsequent handling of the elements prior to loading in a reactor, there exists a definite need for nondestructive analytical procedures, not only for total uranium, but also for isotopic composition.

At the Materials Testing Reactor, Forbes, Hogg and Turk have developed a nondestructive procedure for analyzing entire fuel assemblies. They irradiate assemblies in a thermal-neutron beam from the reactor and measure the fast fission neutrons produced. Analysis is strictly empirical, done by comparison with a standard, but could be modified by preparation of a curve, since the important quantity is the ratio of fast neutrons to thermal neutrons. Although they use a neutron beam from the MTR, the procedure should be adaptable to relatively small neutron sources.

A BF_3 neutron-counting tube in the beam hole of the reactor measures the flux incident on the assembly being tested. At right angles to the incident beam two BF_3 tubes are mounted in cadmium-covered boxes filled with paraffin. The cadmium serves to attenuate thermal neutrons while the paraffin slows the fast neutrons to near thermal energies so they can be detected by the BF_3 tubes. Accuracy for highly enriched uranium is within 1%. The estimated cost, not including the neutron beam, is $3,000.

Remley and Engholm (Atomics International)* have adapted a zero-power reactor to nondestructive testing. Reactor instrumentation is set to maintain a constant neutron flux by automatic regulation of a calibrated control rod. Thus the change in control-rod position due to insertion of an "unknown" can be compared to the change caused by insertion of a physically identical standard. If all other factors are constant, a U^{235} difference of 0.0009 wt% can be detected in material at 1% U^{235} concentration.

Although on first inspection it would seem that procedures requiring a reactor would be prohibitively expensive, the procedures have two distinct advantages. First, the material being tested is not destroyed. With fabricated fuel elements this is a very important consideration. Second, small research reactors have innumerable uses, and a company having a reactor can adapt it to isotopic analysis at very little expense and without affecting its utility in other projects.

Gamma Counting

All isotopes of uranium are naturally radioactive. For U^{235}, the 0.184-Mev gamma is the most convenient analytical tool. Upson and Miller (General Electric Co.) and Reynolds and Eldridge (ORNL) all have investigated gamma-counting procedures. The procedure involves counting the 0.184-Mev gamma either alone or in proportion to a 0.10-Mev gamma. Accuracy can be better than 3% of the U^{235} concentration with a sample volume of 2 ml. At ORNL it was decided that samples should be extracted to remove daughters, but at GE the circumstances were slightly different and separation was not considered necessary.

Alpha Counting

In a somewhat related procedure, H. Louise Smith (Los Alamos) uses an alpha-pulse analyzer to determine most of the uranium isotopes. The precision and applicability of this method depend on the relative abundance and half-lives of the isotopes in the mixture and the spacing in energy of the characteristic alphas emitted by the isotopes. The alphas should have energies differing by 150 kev or more to distinguish accurately between the groups.

For example, U^{236} emits an alpha with an energy between those of two alphas emitted by U^{235} (Table 2). For this reason, unless the U^{236} is relatively abundant it cannot be detected in a mixture containing U^{235}.

The alphas emitted by isotopes having long half-lives, such as U^{238}, or whose concentration is low in comparison to other isotopes in the sample, may not be distinguishable in the spectrum. Other methods are then used to detect such isotopes. Conversely, trace amounts of an isotope with a short half-life, such as U^{232}, can be detected by alpha analysis even when all other methods including the mass spectrometer fail.

A Look Ahead

It appears likely that the mass spectrograph will continue to be the standard method for some time to come. For destructive analysis, the emission spectrograph is in common use, and it seems likely that its U^{236} problem will be resolved with time. Reactor fuel elements and other materials requiring nondestructive analysis present a difficult problem, with the zero-power reactor appearing to be the most probable solution.

None of the methods is inexpensive, nor does it appear likely that an inexpensive method of analysis will appear soon. Much remains to be done, but the direction of effort is to a large extent dependent on the conclusions of the reactor technologists as to the type of reactors to be built.

* Aerojet-General Corp. has developed a very similar technique for its reactor (NU, June '57, p. 134).

Food-Irradiation Reactor

This conceptual design uses an MTR core and an indium-sulfate blanket that circulates to an adjacent 3,000-megarep-ton/day irradiation facility

By D. T. BRAY and C. F. LEYSE
Internuclear Company, Clayton, Missouri

THE ARMY QUARTERMASTER CORPS has been investigating the feasibility of using ionizing radiation to preserve food since 1953. At this stage of the research large sources of radiation are needed for pilot-plant studies. One possible source is a nuclear reactor, and our company was commissioned to make a preliminary design study (NU, Oct. '56, p. R-5).

Briefly, primary specifications are:

1. Processing of 3,000 lb of food per hr at a dose of 2×10^6 rep (1.66×10^8 ergs/gm); that is, a production rate of 3 megarep-tons/hr
2. Maximum dwell time for certain foods of 24 min
3. Maximum integrated neutron flux of 1.7×10^7 n/cm^2
4. Dose variation within 100–125% of design figure

Conceptual Design

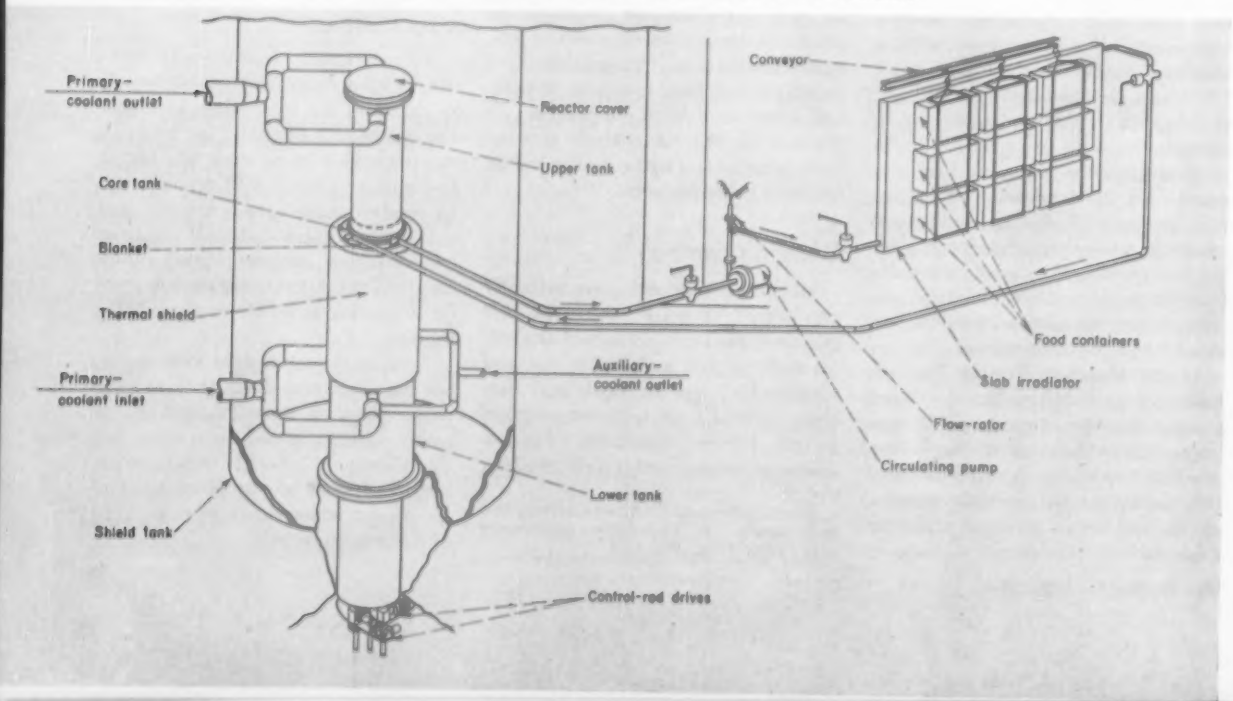
A conceptual design for a reactor-irradiator system to meet the Quartermaster Corps requirements is shown in Fig. 1. The reactor has an MTR-type core surrounded by a light-water solution of indium sulfate. This solution is circulated between the blanket and irradiators in another building in which food is irradiated. Design data are in Table 1.

Reactor. The core consists of 24 MTR-type assemblies of 2½-in. square cross section, 3 ft long. It is contained in an aluminum pressure vessel of 18½-in. o.d. and ⅜-in. wall. Around the reactor vessel is the blanket tank, which, in turn, is surrounded by a 3-in. steel thermal shield. This entire assembly is located in a 10-ft-diameter water-filled shielding pool. The control rods enter the reactor from below. A separate circulating system, not shown, provides cooling for the blanket.

Figure 2 is a cross section of the reactor. Five shim safety rods are arranged in a cross pattern. Two regulating rods are provided at the core periphery. Between core and vessel are aluminum filler blocks. With these the fast leakage from the core is greater than it would be if the spaces were water filled.

Figure 3 is a plan view of the reactor and the adjacent irradiation facility.

FIG. 1. System uses blanket that becomes radioactive in reactor, then flows to food irradiators



Three below-grade levels in the reactor building are used for the primary-reactor-cooling-system equipment, including such items as a heat exchanger, pumps, purification equipment, etc.

Radiator building. Immediately adjacent to this building is the radiator building. It contains four gamma irradiators and the equipment associated with circulating the indium-sulfate solution. Located at the lower level are storage tanks for radioactive indium solutions and cleanup solutions. The major equipment associated with the indium system is located in the equipment pit. The radioactive equipment is in the lower level, and that equipment which is not radioactive is in the upper level.

The reactor pool is offset to one side of the reactor building. This decreases the size of the building necessary to provide working space around the reactor. In the radiator building are pits for the indium-system equipment and also four irradiator cubicles. Two slab-type irradiators and two drum-type irradiators are shown.

The slab-type irradiators are provided for irradiation of food in boxes, sides of beef, whole hog carcasses, and other irregularly shaped articles in baskets, bags, etc. The two drum-type irradiators are provided particularly for the irradiation of number-2 cans and number-10 cans. A number-2 can is about 3½ in. in diameter and 4½ in. long.

Each drum irradiator consists of a series of parallel tubes through a drum containing the indium-sulfate solution. The drum-type irradiator has advantages in that relatively low maximum-to-minimum dose ratios can be obtained in the products, and also that reasonably high reactor-irradiator efficiencies can be achieved with relatively short dwell times. The number-2-can irradiator has 61 parallel tubes arranged in a triangular lattice. Each tube contains 15 cans giving a total weight of food in the drum of approximately 1,200 lb and a dwell time of 24 min for 3,000 lb/hr.

Power level. Although a reactor power level of only 10.5 Mw is required to meet the production requirements, the reactor is designed for 20 Mw, first, to account for uncertainties in the design and, second, to permit more rapid startup of the reactor-irradiator system. For example, operation at normal power for 5 hr is necessary to reach 95% of equilibrium activation in the indium solution at the 10-Mw level. At 20 Mw, however, the time required to reach the required activity level in the indium solution is less than an hour.

The over-all efficiency of the reactor-irradiator complex and thus the reactor power required to meet specifications are affected by many parameters. In brief these include the following: (a) reactor-core size, shape, and composition, (b) blanket thickness and volume, (c) density (concentration) of indium-sulfate solution, (d) irradiator volume and geometry, (e) volume of pumps, valves, heat exchanger, etc., in the blanket-irradiator system, (f) volume and geometry of food packages. Parametric studies involving these quantities led to the selected reactor core and blanket dimensions and gamma irradiator dimensions.

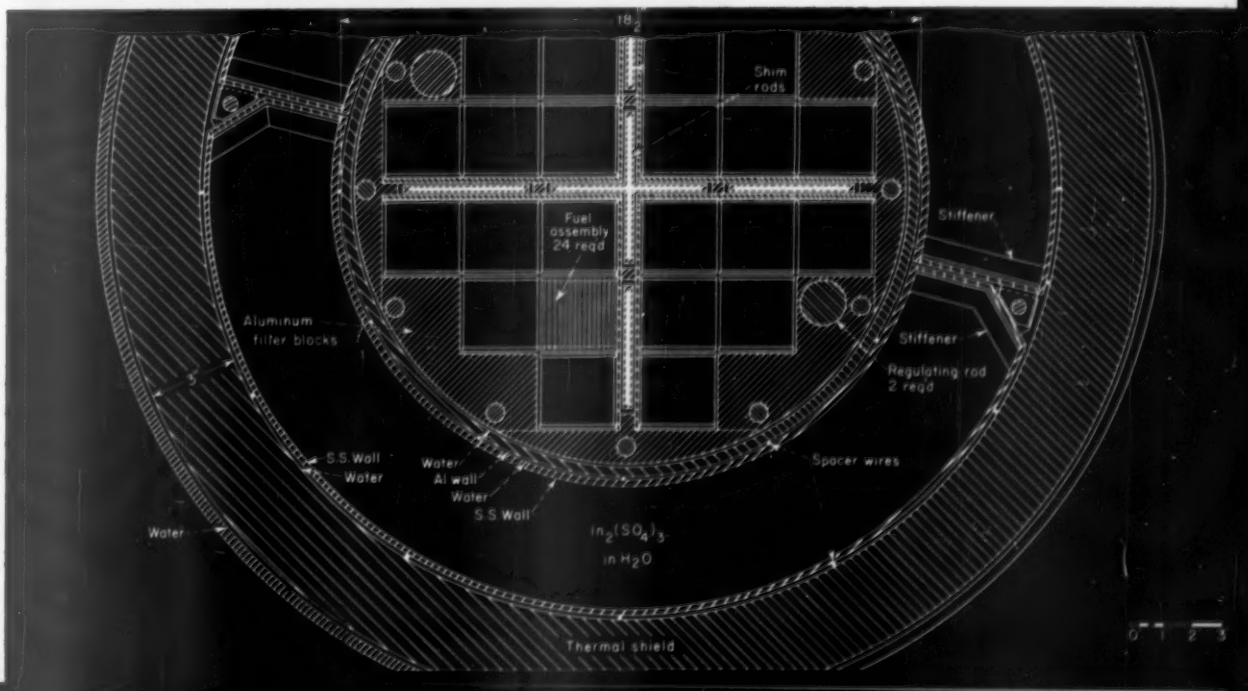
TABLE 1—Reactor-Irradiator System

Design power	20 Mw
Normal operating power	10.5 Mw
Power absorbed in food	7 kw
Over-all plant efficiency	0.067 %
Output	3 megarep-tons/hr
Diameter, equivalent circular core	14.9 in.
Height of core	36 in.
Metal-to-water ratio (avg)	0.7
U^{235} content of new clean core	11.4 kg
Cold clean critical U^{235} mass	6.0 kg
Operating pressure	150 psig
Coolant inlet temperature at reactor	133° F
Coolant outlet temperature	190° F
Indium-solution density	1.4 gm/cm³

Why This System?

Five basic types of gamma rays are available from a reactor system:

FIG. 2. Core is designed with enriched fuel, aluminum filler blocks to increase number of blanket neutrons



prompt, capture, inelastic scatter, fission-product, and beta-decay gammas. Altogether 6–12% of the fission energy appears as gamma energy. However, only the gammas that follow beta decay occur long enough after the neutronic event that produces them to permit their use away from the core. These include fission-product-decay gammas and gammas from neutron-activated radioisotopes such as the indium used in the proposed design.

Direct core gammas might be used by filtering out neutrons with a water shield. This is inefficient. Moreover, photoneutron production in deuterium contained in the water becomes predominant for shields thicker than 200 cm and limits gamma dose in the food to ~20,000 r. With this water thickness a 750-Mw reactor is required for 3 megarep-tons/hr.

Fission-product-decay gammas can be used as direct core gammas or taken from spent fuel elements, separated fission products, circulating fuel, or gases evolved from homogeneous reactors. The last two are discussed below.

Circulating fuel. The possibilities of homogeneous reactors can be illustrated with aqueous systems. Use of circulating fuel is plagued by the neutron-tolerance problem. Here the neutron source consists of delayed neutrons, neutron multiplication in the irradiator, and photoneutrons. Three possible arrangements suggest themselves: (a) a direct gamma irradiator, with too many neutrons, (b) a water-shielded irradiator, discussed previously, and (c) a system with a holdup tank to eliminate neutrons. The last system involves large U^{235} inventories and large gamma losses because of the fuel in the holdup tank. In general, increase of neutron tolerances by 10^4–10^5 is necessary before circulating-fuel irradiation can be seriously considered.

Off-gases. The use of off-gases from homogeneous fuel is more attractive. About 40% of all fission products are off-gases at one time or other during their lives. However, not all gases are easily liberated from solution. The xenon and krypton are given up most readily. The amount of available energy in gas form is not well known, but it is estimated to be about 0.25% of reactor power. The neutron flux associated with off-gases appears acceptable. The gammas have the disadvantage of wide energy spectrum giving problems in maximum-to-minimum dosage ratios in food. Since more of the reactor power can be attained by other means with better developed systems, the use of this source was not pursued.

Circulating Blanket

Detailed consideration is given to the use of excess neutrons to produce gamma sources. One can expect to use up to a maximum of 1.0 neutron per fission. Highly enriched fuel must be used; otherwise U^{238} will soak up the excess. Activation should be accomplished in the blanket. A parent gamma producer in the core competes with U^{235} for neutrons. This raises the critical mass and the amount of the gamma producer required.

One might use a homogeneous mixture of parent isotope and core coolant. However, this leads to a large volume of parent-isotope solution because of piping, heat exchanger, etc. In addition the use of soluble salts could lead to problems of deposits on heat-transfer surfaces, particularly in the core.

With leakage neutrons, however, the parent gamma producer does not have to compete with U^{235} but only with its own compound affiliates and the moderator and structural materials. By suitable adjustment of core dimensions nearly all the excess neutrons can be made to leak out of the core into a blanket. Also the amount of parent gamma producer outside the gamma irradiator can be kept small.

For the given specifications, the use of a blanket system is clearly indicated. The choice of a core type to produce

AEC Lets FIR Contract

On May 15, 1957, the Atomic Energy Commission announced through its San Francisco Operations Office that it had signed a $125,000 contract on a cost-plus-fixed-fee basis with Kaiser Engineers for research and development relating to the design of the Food Irradiation Reactor. This is preparatory to engineering design and construction (NU, April '57, p. 28).

The AEC plans to construct the reactor at the Sharpe General Depot, Stockton, Calif., as part of an ionizing-radiation center.

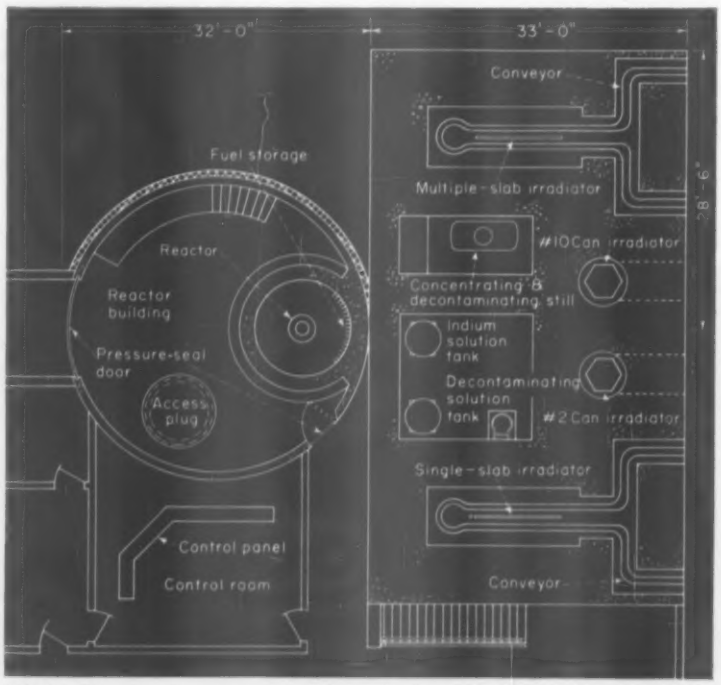


FIG. 3. Plan view shows reactor building and adjacent irradiation facility. Reactor is offset in building to increase working space. Two slab irradiators and two drum irradiators process food

the excess neutrons is nearly independent of the blanket system. Many types of cores can be used to produce the necessary leakage.

At this point one must consider volume efficiency, defined as the ratio of the number of disintegrations occurring in the irradiator to the total number of disintegrations of the gamma emitter. This ratio must be high to obtain relatively high over-all efficiencies.

If the cycle time is short, say less than half of the gamma emitter's half-life, volume efficiency is essentially equal to the ratio of the respective volumes. Thus small blanket volumes are strongly favored, and the use of small cores is indicated. This, in turn, calls for a fully enriched, light-water-moderated and -cooled reactor. Because of the stage of its engineering development we chose an MTR-type core. However, at much higher production rates the use of a liquid-sodium–beryllium-oxide blanket becomes more attractive since larger blanket volumes can be tolerated.

The combination of dose, dwell time, and throughput dictate a small gamma irradiator. The requirement on volume efficiency limits the amount of material outside the irradiator.

Choice of Parent

Table 2 gives a list of the most interesting elements for the blanket together with the more important properties affecting the choice of a satisfactory parent gamma producer. The elements are listed in order of the gamma energy available per neutron absorbed, which is the first criterion.

To be absorbed effectively, the fast excess neutrons must be slowed down to thermal energies. None of the acceptable moderators is among the good gamma producers in Table 2. Therefore moderator and parent gamma producer must be mixed in some manner (not necessarily homogeneously) and the gamma producer must compete for excess neutrons with the moderator, its compound affiliates, and any structural material present. This fact eliminates consideration of aluminum and speaks strongly against sodium. High cross sections are obviously desirable, and indium, with its 190-barn thermal cross section plus its resonance peaks, stands out in this respect.

When solutions of salts and water are considered, solubility becomes important. The higher the concentration the better the competitive position for excess neutrons. The choice of compounds of the interesting isotopes is often limited. Lanthanum apparently cannot be used in solution form for this reason.

TABLE 2—Elements Promising as Gamma Producers

Element	*Gamma energy per neutron absorbed (Mev)*	*Capture cross section (barns)*	*Half-life, important isotope*
Na	4.14	0.50	15 hr
Co	2.53	37	5.3 yr
La	2.44	8.9	40 hr
Sc	2.09	24	85 days
In	1.81	190	54 min
Al	1.80	0.23	2.3 min
Ga	1.73	2.77	14.2 hr
Mn	1.73	13.2	2.58 hr
Cs	1.54	29	2.3 yr
A	1.29	0.62	109 min

One must also consider half-life. After a neutron has been absorbed in an isotope, that particular atom must be transported to the gamma irradiator. Half-lives of less than a minute are probably of little use. On the other hand, isotopes with long half-lives, such as cobalt and scandium, present problems in startup and shutdown.

The gamma spectrum affects the energy deposit in the food. Gammas of too high an energy will go right through thin packages and deposit too small a fraction of their energy. Low-energy gammas, on the other hand, deposit their energy at the surface and give too small a depth dose, increasing the maximum-to-minimum dose ratio. Thus the optimum gamma energy depends primarily on the food thickness. The thicker the food, the more energetic is the optimum gamma—up to the 2.23-Mev threshold of deuterium where photoneutrons enter the picture and lead to induced radioactivity in the irradiated food.

Of the elements listed in Table 2, indium, manganese, and possibly scandium and lanthanum appear to have the best over-all combinations of properties for the present application.

Blanket Design

The choice up to this point has been straightforward. The choice of an exact type of blanket becomes more involved. Systems investigated included indium salts in light and heavy water, manganese sulfate in light and heavy water, liquid sodium moderated with beryllium oxide, and, to a lesser extent, the use of movable solid scandium and lanthanum. Scandium and lanthanum do not look good in solution systems because of half-life and solubility problems, respectively, but both may be interesting in a movable-solid system. Manganese and indium salts can both be considered in a solution-type system although manganese probably requires the use of expensive heavy water.

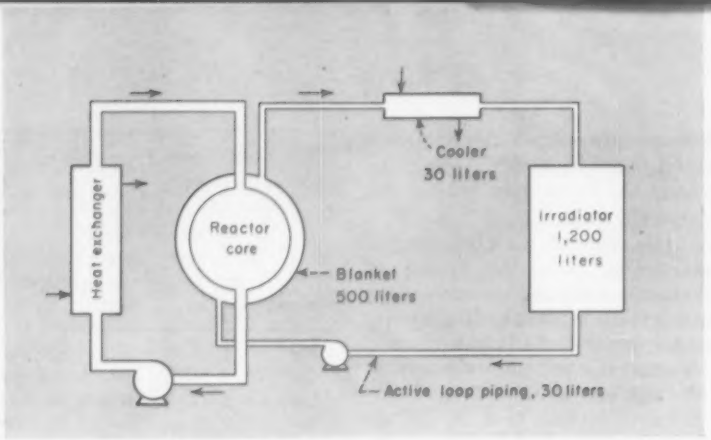
There are several disadvantages in the use of solid scandium or lanthanum as compared with indium or manganese in solution: (a) The startup time for the gamma "power" is longer. (b) One may have difficulty obtaining the short dwell time for the food. (c) Arrangements of the solid in the gamma radiator as a function of time to give proper maximum-to-mimimum dose ratios will give operational headaches. (d) The gamma spectra of scandium and lanthanum are not as attractive as those of indium and manganese. (e) Any long shutdown of the food-processing plant would result in poorer over-all efficiency as the reactor must run all the time, at least with scandium. (f) The reactor-containment-vessel design will be more difficult because of the type of movement between radiator and reactor blanket.

On the other hand the solid system has some advantages over the indium- or manganese-solution system: (a) The danger of spills or leaks of large quantities of radioactive material is much less. (b) Reactor operation may possibly be simpler. (c) Scandium and lanthanum have more energy per neutron absorbed. (d) There are no corrosion, crudding, or precipitation problems.

These considerations will become more important when larger food-irradiation systems are built.

* * *

This work was done under contract to the AEC, and the authors are grateful for permission to publish it. The article is based on a paper presented at the December 1956 meeting of the American Nuclear Society. The authors wish to acknowledge the contributions of other members of the staff of Internuclear, particularly G. E. Putnam and W. R. Pearce, and the helpful comments and criticism of the AEC and QMC personnel associated with the study.



REACTOR-IRRADIATOR SYSTEM has 17-Mw reactor of 40-cm radius. Irradiator contains 1,200 liters of indium-sulfate solution with a decay strength of .19 $\times 10^{11}$ indium decays/sec/cm^3

Reactor-Irradiator for Meat

Design considerations suggest the feasibility of a system using a low-temperature reactor, a slab irradiator, and an indium sulfate blanket to process beef at 1.6¢/lb

By E. O. GUERNSEY
Socony Mobil Oil Co.
Paulsboro, New Jersey

and R. M. BALL
Babcock and Wilcox Co.
Lynchburg, Virginia

A STUDY OF beef processing with reactor radiations has led us to the conclusion that such processing is feasible. One satisfactory way to produce the radiation is to activate a blanket solution and circulate it to an irradiation facility (see figure). The cost of such processing is at least competitive with accelerator processing.

Our problem was defined as the choice, conceptual design and evaluation of a reactor-irradiation system capable of delivering a 2-Mrep dose (= 1.66×10^8 ergs/gm) to 80,000 lb of beef in $6 \times 16 \times 20$-in. packages. Operating time was set at 10 hr/day and processing time at ~10 min. Dose for every portion of the meat processed was to be 100–125% of the design figure.

We found that the most difficult specification to meet was the 10-min processing time. Longer processing times lead to economies and do not otherwise appear to affect results appreciably. Further considerable savings can be achieved by designing for continuous operation. With 10-hr/day operation, xenon poisoning is nearly at a maximum when it is time to restart the reactor. Thus one must design for large excess fuel loading.

Costs

We estimate beef sterilization cost at 3.1 cents/lb in a system that meets Quartermaster Corps specifications except for having a 100-min processing time. Continuous operation of the same system reduces the cost to 1.3 cents/lb. If the system is scaled down to process continuously the same quantity of meat as can be processed in five 10-hr days per week, the processing cost is 1.6 cents/lb.

Irradiation Facility

For mechanical simplicity and minimum self-absorption we chose a rectangular irradiator. The carton size, geometry and permissible dose variation then determine the best method of operation of the process line. Solutions for various types of possible arrangements led us to select a two-pass system in which cartons pass the irradiator twice on each side. The cartons shift without turning at conveyor bends so that both sides of the cartons are equally exposed.

A disadvantage of the rectangular irradiation volume is the edge effect—nonuniform dose resulting from limited source-package overlap and the escape of nonreflected photons from the ends and sides of the package. Analysis leads to a transcendental equation that can be solved graphically.

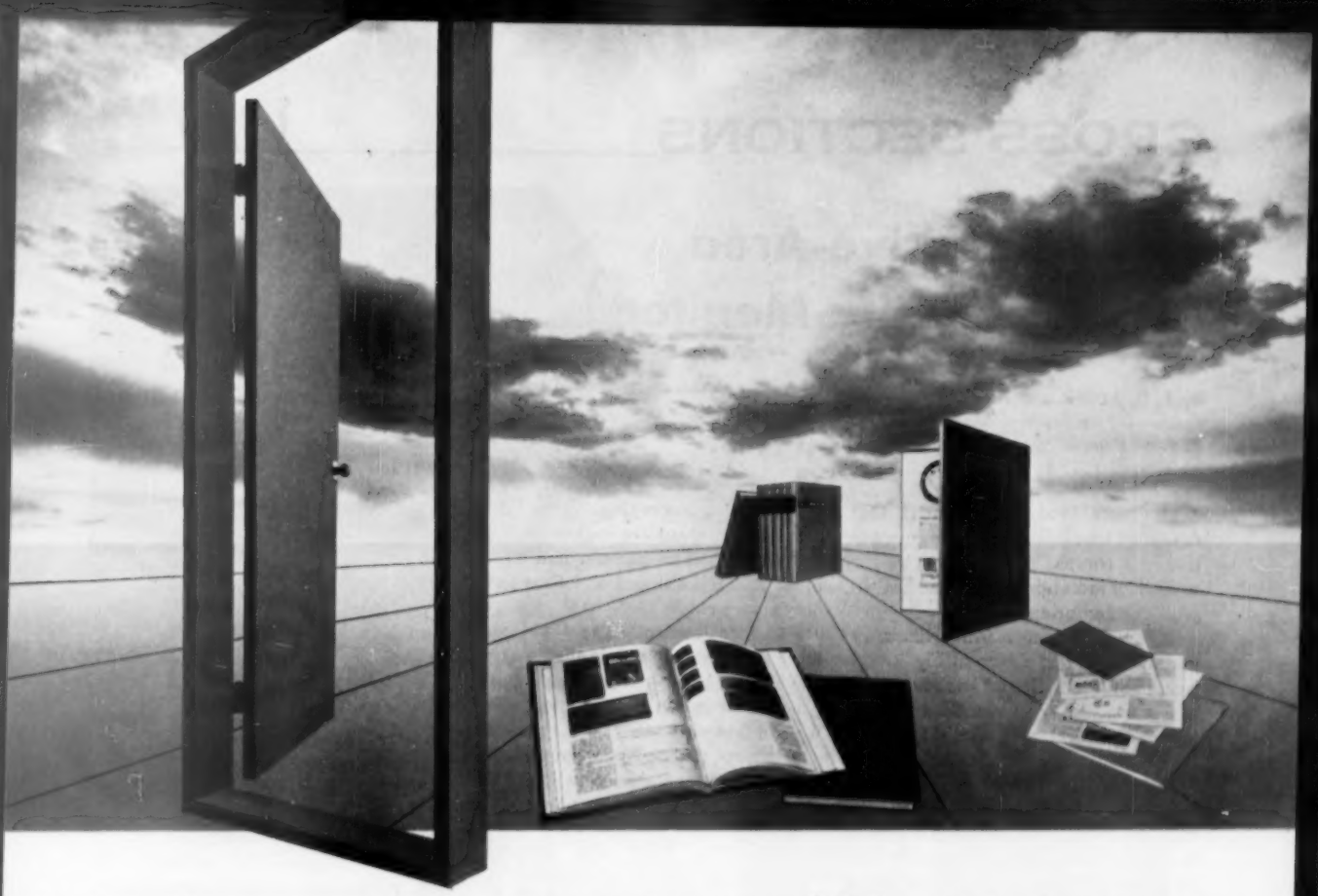
Reactor

We used a graph to specify completely the volume and decay strength (Mev/cm^3/sec) of active solution required in our irradiation facility. The number of neutron captures required in the reactor can then be determined. It is proportional to the source volume times its strength divided by the volume efficiency.

Another design consideration is the disposition of reactor heat. It can be dumped or used to produce power or process heat. If it is to be used, the reactor coolant solution must be at higher pressures and temperatures than otherwise, and fuel cladding must be zirconium or stainless steel. Our computations show that the increased costs involved in making the heat available as power or process heat are greater than the credits obtained. Beef-processing costs rise to about 5.4 cents/lb.

* * *

This study was undertaken as a 1955 summer problem at the Oak Ridge School of Reactor Technology. Other members of the design group were T. V. Kavanagh, C. T. McDaniel, G. T. Schnurer, and C. E. Whittle. R. N. Lyon, R. W. Peelle, and H. R. Zeitlin of ORNL were group consultants. Their help is gratefully acknowledged. Full details of the study are in ORNL report CF-55-8-190.



At Los Alamos you have opportunity to publish original research

During 1956 research scientists at Los Alamos Scientific Laboratory submitted 402 articles for publication in technical journals and presented 126 papers at professional society meetings. These contributions to the scientific literature came from many fields, including some usually considered to be limited by classification. For example, the following are among the numerous recently published papers by members of one of the major weapons divisions:

THE HYDRODYNAMICS OF A REACTING AND RELAXING FLUID
W. W. Wood and J. G. Kirkwood, J. App. Phys. **28**, *395 (1957).*

COMPRESSION OF SOLIDS BY STRONG SHOCK WAVES
M. H. Rice, R. G. McQueen, and J. M. Walsh, Solid State Physics—Advances in Research and Applications, Vol. **6** *(In Press).*

PRECISION FLASH X-RAY DETERMINATION OF DENSITY RATIO IN GASEOUS DETONATIONS
R. E. Duff and H. T. Knight, J. Chem. Phys. **25**, *1301 (1956).*

POLYMORPHISM OF IRON AT HIGH PRESSURE
D. Bancroft, E. L. Peterson, and S. Minshall, J. App. Phys. **27**, *291 (1956).*

IMAGE QUALITY CRITERIA DERIVED FROM SKEW TRACES
F. A. Lucy, J. Opt. Soc. Am. **46**, *699 (1956).*

VISIBLE RADIATION FROM HELIUM IN A STRONG SHOCK WAVE
G. E. Seay and L. B. Seely, Jr., Bull. Am. Phys. Soc. **II, 1**, *227 (1956) (Abstract).*

Opportunity for scientific recognition is only one of the reasons why scientists enjoy working here. Los Alamos is attractively situated at an elevation of 7,300 feet in the pine-covered mountains of northern New Mexico. Now an open city, it offers an ideal environment for enjoyable family living.

Applications from qualified scientists and engineers may be addressed to:

DIRECTOR OF PERSONNEL
LOS ALAMOS SCIENTIFIC LABORATORY
Division 1908
Los Alamos, New Mexico

los alamos
scientific laboratory
OF THE UNIVERSITY OF CALIFORNIA
LOS ALAMOS, NEW MEXICO

Los Alamos Scientific Laboratory is a non civil service operation of the University of California for the U. S. Atomic Energy Commission.

Large-Sensitive-Area Portable Alpha Monitor

By F. D. RYDER and H. V. HARDISON
Instrument Development Division, Savannah River Laboratory
E. I. du Pont de Nemours & Co., Aiken, South Carolina

The portable alpha monitor (PAM) described here provides the large sensitive area, compactness and light weight needed for radiation-control and health-physics monitoring.

The PAM housing is 6 in. in diameter and 8 in. high, as shown in Fig. 1. A 5-in. photomultiplier tube is coupled to a 24-in² ZnS (Ag) scintillator. An aluminized Mylar (Wakefield Industries) light shield is bonded to the scintillator.

The photomultiplier feeds a counting-rate circuit. Most of this circuit is contained in a plug-in assembly can. Readout consists of a dual-range meter and headphones.

Photomultiplier high voltage is supplied from a transistorized plug-in supply (Universal Atomics model UAC-1000), powered by small mercury cells. The complete circuit is shown in Fig. 2.

The instrument glides on ball bearings, which are mounted in a 3/8-in.-thick, 3/8-in.-wide aluminum bottom support ring. The bottom surface of the monitor is about 1/4 in. from the surveyed surface. Although the Mylar will not resist abrasion, we have had no trouble maintaining a lighttight seal. Recently we made a model with a metal screen to protect the Mylar; the instrument suffered a negligible loss in sensitivity.

In a field evaluation, the PAM showed marked superiority over a Samson-type survey meter in at least seven respects:

Response. The PAM net counting rate was twice that of the Samson for a 700-dpm plutonium source. With a 227-dpm source, the PAM indicated ~100 cpm, whereas the Samson failed to respond.

Position sensitivity. PAM indication was independent of alpha-source position relative to the center of the monitor's sensitive area. The Samson had to be centered directly over the source.

Continuous surveying. The PAM surveyed a flat surface continuously at 2–3 in./sec. The Samson had to be lifted and repositioned and thus gave only a spot check.

Shock resistance. The PAM was more shock resistant than the Samson. It was also insensitive to electrostatic charges, air currents and motion, all of which affected the Samson.

Warmup time. No warmup time was required for stable operation of the PAM, while the Samson required 30 min.

Drift. The PAM was drift-free. The Samson had to be rezeroed frequently during extended surveys.

Beta-gamma sensitivity. The low levels of beta-gamma contamination generally encountered in survey work did not disturb the PAM's reading, while the Samson did respond to interfering contamination.

* *

The work reported here was performed under U. S. Atomic Energy Commission contract AT(07-2)-1. AEC permission to publish is gratefully acknowledged.

FIG. 1. Portable alpha scintillation monitor. Composite photograph shows position of components inside 1/16-in.-thick aluminum housing. Instrument weighs 5.3 lb

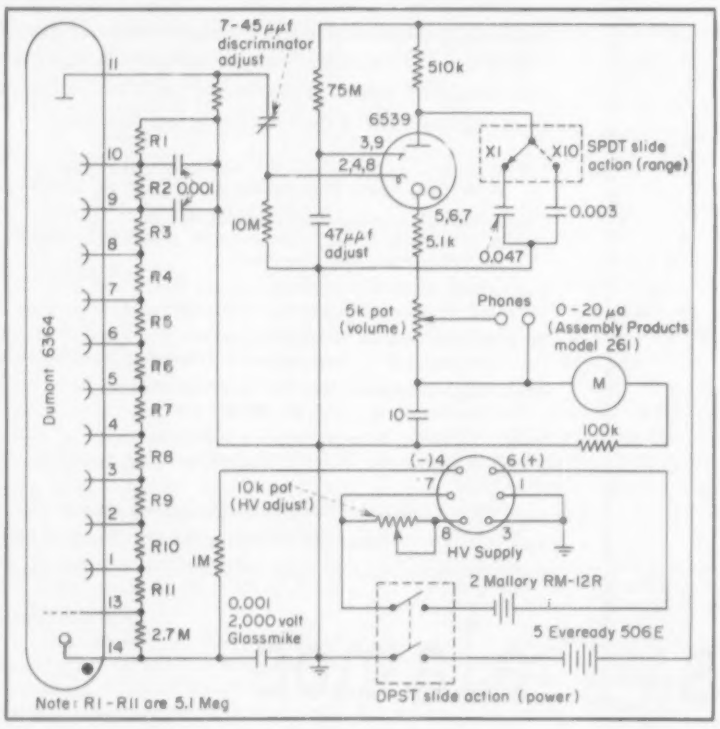
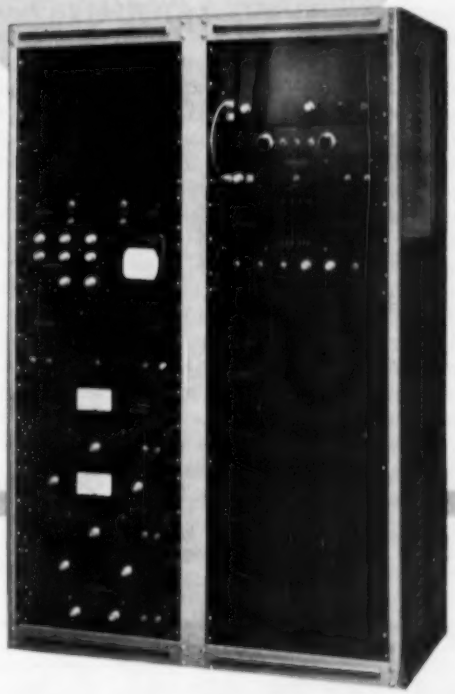


FIG. 2. Alpha-monitor circuit diagram

RIDL
introduces the new 200 CHANNEL ANALYZER

200 CHANNELS WITH THE SIMPLICITY AND RELIABILITY OF 100 CHANNELS



The new RIDL 3302, 200 channel analyzer offers all the advantages of a 256 channel analyzer, without sacrificing the simplicity, reliability and economy of the 100 channel analyzer. The design simplicity of the 200 channel unit results in low initial cost, easy low cost maintenance, simple operation and prompt delivery.

The memory may be used as a whole or divided into halves with data stored in each half.* This feature is very useful in cases where the readout of data is impractical or undesirable in the interval between measurements because of rapidly decaying or growing energy levels.

OPERATING CHARACTERISTICS

- Burroughs beam switching tubes greatly simplify address circuits.
- A simple computer logic used to program computer and other non-storage functions.
- Dead time 16 μ sec plus ½ μ sec per channel with dead time correction factor to correlate data regardless of energy distribution or counting rate.
- Maximum counting rate without distortion or shift of data: greater than 5×10^6 CPM.
- Normal window width ½%, may be set to any optional value and the 200 channels located in any region of the spectrum with no drift.
- Linearity better than 0.2%.
- Analyzer may be operated in coincidence with external pulses, either prompt or delayed.
- Accurate linear cathode ray tube presentation of data during and after measurements.
- Analyzer subtracts or adds at operators option in order to permit automatic background subtraction.
- Precision recording or decimal printed readout which totals every 10 or 100 channels with channel numbers printed directly, 1 to 200.
- Capacity per channel, 65,536 counts.
- RIDL provides a two day instruction class on the operation and maintenance of the analyzers free.
- Installation may be done by an RIDL factory engineer at an additional cost.
- Services can be supplied by factory engineers on a time and material basis.

*On special order the analyzer will store in 100 channels while simultaneously printing out of the other 100 channels.

WRITE FOR DETAILS

RADIATION INSTRUMENT DEVELOPMENT LABORATORY

5737 SOUTH HALSTED STREET • CHICAGO 21, ILLINOIS

Simple Recording Gamma-Ray Spectrometer

By WILLIAM H. VENABLE, Jr.*
University of Florida, Gainesville, Florida

An automatic gamma-radiation spectrometer was built at the University of Florida for laboratory instruction and research. It is versatile, relatively inexpensive and sufficiently accurate for these purposes.

The scintillation spectrometer is standard up through the linear amplifier. It consists of a Harshaw canned sodium iodide crystal mounted on a DuMont 6292 photomultiplier tube. The high-voltage supply is Atomic Instrument Co.'s model 312. A cathode follower at the base of the photomultiplier relays the signal to an Atomic model 204-C linear amplifier.

The first modification of the equipment for automatic spectroscopy occurs in the Atomic model 510 single-channel differential pulse-height analyzer. An electric clock motor drives the baseline dial at a constant speed, adjustable from 0.25 to 0.66 rpm. The entire range of 0–100 volts pulse height is covered by 10 turns of this dial. A cathode follower was installed to follow the voltage across the baseline potentiometer, this voltage being proportional to the baseline dial setting. The output of the cathode follower deflects the beam of an oscilloscope in the "x" direction in direct proportion to the pulse sizes that are passed by the analyzer. A belt drive to the window-width potentiometer of the analyzer provides a window that is always 0.7% of the baseline voltage.

The analyzer output passes into a counting-rate meter, whose output is used to deflect the oscilloscope beam in the "y" direction. Thus, when the baseline dial is driven through its range, the oscilloscope beam traces out a differential pulse-height analysis curve that is recorded on a time-exposed photograph.

* PRESENT ADDRESS: Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

Calibration

Calibration in the x direction is accomplished by sweeping the oscilloscope beam in the y direction. This line is photographed in known x positions obtained by handsetting the baseline dial of the pulse-height analyzer.

The y calibration is recorded similarly, sweeping the oscilloscope beam in the x direction and positioning the resulting scope trace line either by applying pulses at a known rate to the counting-rate circuit or by applying d-c voltages representing counting-rate meter output to the oscilloscope y amplifier. The former method is probably more accurate, but, because of its simplicity, we used the latter.

This calibration procedure requires constant oscilloscope-amplifier gain during the exposure of the curve and calibration. If this condition is met, the calibration is independent of magnification and truncation of the curve obtained by presetting the oscilloscope amplifiers. The calibration is also independent of gross distortions due to nonlinearity of the oscilloscope and photographic distortions.

Limitations

Errors caused by drift in d-c amplifiers during the run can be a most serious problem with commercial oscilloscopes. However, this difficulty can be minimized by keeping the amplifiers in

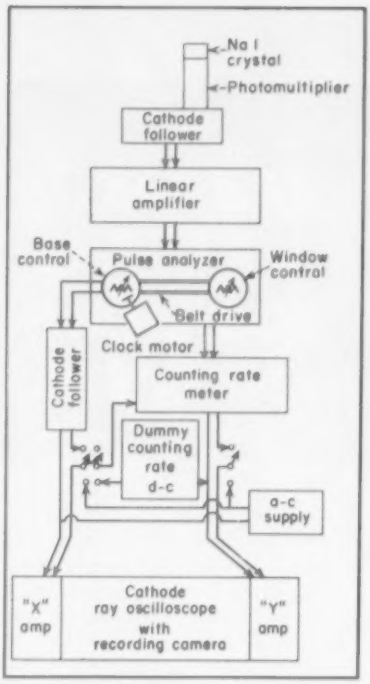


FIG. 1. Recording γ-ray spectrometer Double-pole switch (left) controls x sweep and dummy counting-rate input for y calibration; single-pole switch controls y sweep for x calibration

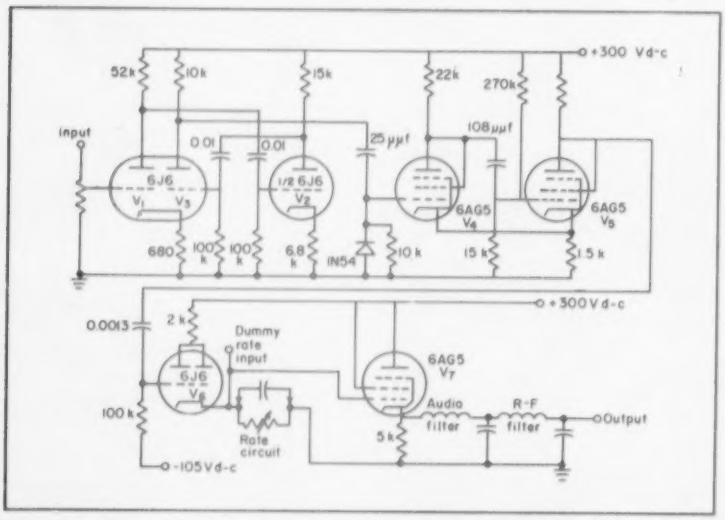


FIG. 2. Counting-rate meter. First three stages and crystal diode provide pulse to trigger univibrator once for each negative pulse larger than predetermined size. Positive pulse from univibrator (V_4, V_5) allows V_6 to conduct at maximum current for pulse duration, charging rate circuit (representative components—15-μf oil-filled capacitor, 0.5-megohm resistor). Filters after V_7 remove small, high-frequency-induced fluctuations and may not be necessary in some constructions

good condition and allowing about 1 hr for warmup before recording.

To keep the spot from fluctuating with the statistics of the decay, a rather long time constant (5–20 sec) was used to give the ratemeter circuit some "inertia." The result is that the ratemeter is reluctant to follow a rapid rise or drop in counting rate. Assuming that the counting rate is fixed, the obvious way to overcome this limitation is a slower sweep speed. This, however, results in a longer run, which increases the chance of amplifier drift. A satisfactory compromise has been worked out between these two factors.

A third limitation results from the details of rather complex spectra being lost in the width of the line drawn by the oscilloscope spot. The practice has been to expand the scale and truncate the curve to include only the part that is of particular interest.

The fourth limitation is brought about by the slowness of the recording. The curve taken directly from the instrument is undistorted only if the half-life of the source is very long (e.g., >3 hr for our instrument) compared with the time the instrument takes to sweep the spectrum or if the radiation varies rapidly periodically (>50 cycles/sec), such as the radiation from a cyclotron-induced reaction in equilibrium. The use of inverse-decay-curve scaling

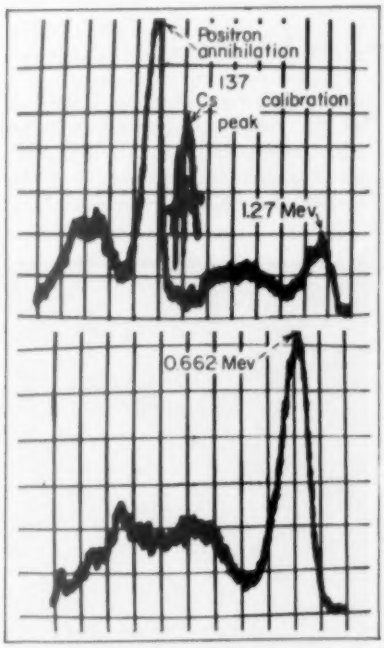
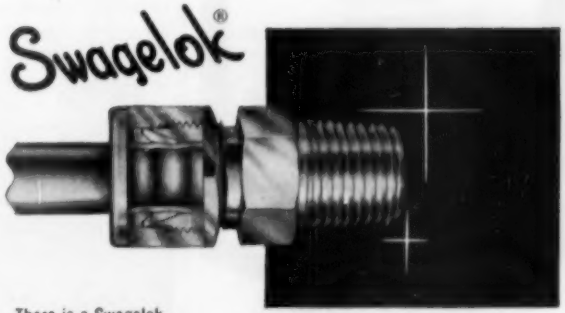


FIG. 3. Differential-pulse-height spectra for Na^{22} (top) and Co^{60}; isolated calibration peaks are from Cs^{137}

Only one name identifies the finest in fittings

Swagelok®



There is a Swagelok Specialist in your area. For catalog, write Dept. J6

TUBE FITTINGS

CRAWFORD FITTING COMPANY

884 East 140th Street

Cleveland 10, Ohio

PROMPT DELIVERY

A GRAM OR A CARLOAD

thorium

OXIDE
(SEVERAL GRADES)

FLUORIDE

NITRATE
AND OTHER SALTS

neutron absorbers

GADOLINIUM

SAMARIUM

EUROPIUM
AND OTHER SEPARATED RARE EARTHS

WRITE FOR TECHNICAL DATA

World's largest producer of rare earth and thorium chemicals for commercial atomic energy use and industrial applications

LINDSAY CHEMICAL COMPANY
272 ANN STREET, WEST CHICAGO, ILL.

factors may be justified in some other cases in view of the difficulty and expense involved in some of the other techniques.

* * *

This work was done under the supervision of D. C. Swanson, University of Florida, and supported in part by the Sperry-Rand Corp.

BIBLIOGRAPHY

1. E. Fairstein. A sweep-type integral and differential discriminator, *Rev. Sci. Instr.* **22,** 761 (1951)
2. R. Hofstadter, J. A. McIntyre. Measurement of gamma-ray energies with one crystal, *Phys. Rev.* **78,** 617 (1950)
3. Gamma spectrometer, *Rev. Sci. Instr.* **26,** 239 (1955)
4. F. E. Terman, "Radio Engineering," p. 590 (McGraw-Hill Book Co., Inc., New York, 1947)

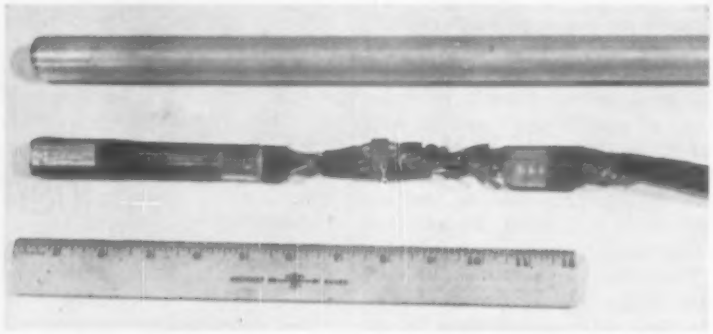


FIG. 1. Photomultiplier head including resistor string (in Lucite cylinder), one-transistor preamplifier and transistor batteries. At top is thimble made of 1-in.-o.d. aluminum tubing for inserting photomultiplier head into critical assembly

Transistorized Photomultiplier Has 0.1-μsec Resolution

By G. S. BRUNSON
Argonne National Laboratory, Idaho Division, Idaho Falls, Idaho

A transistorized photomultiplier circuit was devised for a very small, high-sensitivity fast-neutron counter capable of excellent time resolution. The whole detector (scintillator, photomultiplier, preamplifier and transistor battery) can be packaged in a 1-in.-o.d., 1-ft-long cylinder (Fig. 1). The circuit (Fig. 2) may be of use to others in need of good time resolution.

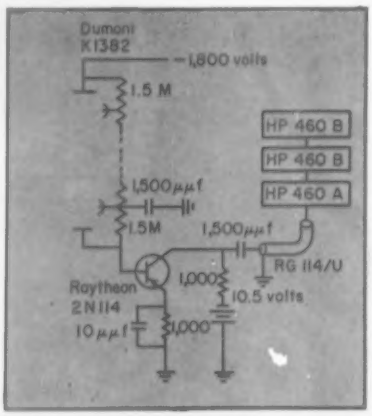


FIG. 2. Compact preamplifier circuit for ¾-in. DuMont K-1382 photomultiplier

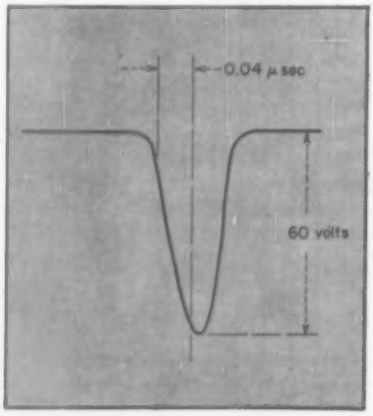


FIG. 3. Typical pulse obtained from circuit in Fig. 2

Since a transistor is current-biased and current-controlled, it is admirably suited for use with a photomultiplier. In this case the transistor is inserted in place of the usual anode resistor. The bleeder network resistors were chosen to give a bleeder current suitable for biasing the transistor used. This type of coupling eliminates the *RC* time constant, which is found in the usual vacuum-tube-type preamplifier where an anode resistor is used to convert the current signal to a voltage signal on the grid.

When Pilot B scintillator is exposed to ~1-Mev gamma rays, the preamplifier delivers ~0.2-volt signal into a 200-ohm load. The time resolution is excellent, the pulses being ~0.1 μsec wide and overshoot virtually nil. Three Hewlett-Packard wide-band amplifiers, two 460-B's and one 460-A, give over-all output up to ~100 volts negative (Fig. 3). Note that 0.04 μsec is the nominal minimum rise time of the Tektronix 531 oscilloscope (with 53C preamplifier) used in this work.

A similar circuit has been used with the RCA 6342 photomultiplier to give equally good results. In this case the Philco 2N128 transistor was used with a different r-c (2,200 ohms, 10 μμf) in the emitter lead. Only the two 460B amplifiers were used since the preamplifier output is ~2 volts into 200 ohms, when a Pilot B scintillator is exposed to 1-Mev gammas.

The circuit parameters do not appear critical. This is probably due to the fact that the oscilloscope is operating at or near the limit of its time response. It is possible that pulse width is considerably less than shown in Fig. 3. Certainly a faster oscilloscope would permit a more careful adjustment of parameters for minimum pulse width. It should be noted that the negative high voltage controls not only the photomultiplier gain but also the transistor bias. Proper adjustment of this voltage is necessary to eliminate overshoot. However, this is not a critical adjustment; anything between 1,600 and 2,000 volts seems to work.

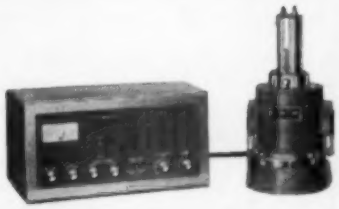
Recovery seems very fast since the oscilloscope at high counting rates will show occasional pulse pairs (both pulses well developed) where the separation is not more than 0.08 μsec. Because of the speed of the pulses, the linearity of the pulse height with incident gamma energy could not be checked on any pulse-height analyzer available. However, oscilloscope measurements indicate a reasonably linear relationship.

NOW...A SCALER with 5 DECADE UNITS!★

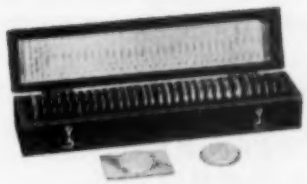
MODEL DS-5 DECADE SCALER

TECHNICAL ASSOCIATES has designed this general purpose nuclear laboratory counting instrument to combine extreme reliability and accuracy with unusual simplicity of operation. Five plug-in decade units permit a direct count up to 199,999, without the use of external registers. Overall resolution time is 1.0 microsecond per pulse pair. Pulse height control allows sensitivity to be varied to facilitate analysis of sample content. "Mono-matic" single lever control starts, stops, and resets count and time, thus simplifying operation and preventing errors.

DS-5 DECADE SCALER can be combined with other T/A accessories to form a complete Laboratory Counting System...

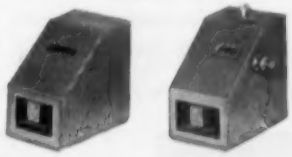


Model DS-5 Decade Scaler shown in use with Model LS-7M Lead Shield and Model SD-1 Scintillation Detector



Model AB-2 Calibrated Absorber Set

Write for complete catalog entitled "Instrumentation for Nuclear Research"



Model CR-1 Count Register and Model PT-1 Predetermined Timer

TECHNICAL ASSOCIATES
Instrumentation for Nuclear Research

140 West Providencia Avenue
Burbank, California

The **KIN TEL MODEL 111** amplifier provides the lowest drift of any commercially available broadband d-c amplifier. The unique circuit incorporates **KIN TEL's** proven chopper amplifier system to provide unsurpassed dynamic performance —unaffected by load or gain changes. Available in a single-unit cabinet or a six-amplifier rack-mountable module only 19 inches wide, the **Model 111** is ideal for data reduction facilities, or as a strain gage amplifier, recorder driven amplifier, or general purpose laboratory amplifier.

SPECIFICATIONS

- ± 2 uv equivalent input drift
- Integral power supply
- ± 35V, ± 40 ma output
- 100,000 Ω input impedance
- 0 to 1000 gain in ten steps
- ± 1% gain accuracy
- 5 uv peak equivalent input noise
- Price (Single) Amplifier $550.00

Representatives in All Major Cities

KIN TEL

[KAY LAB]

5725 KEARNY VILLA ROAD
SAN DIEGO 11, CALIFORNIA

Rapid Method for Dating Nuclear Explosions

By SAIT AKPINAR

Department for Experimental Physics, University of Istanbul, Istanbul, Turkey

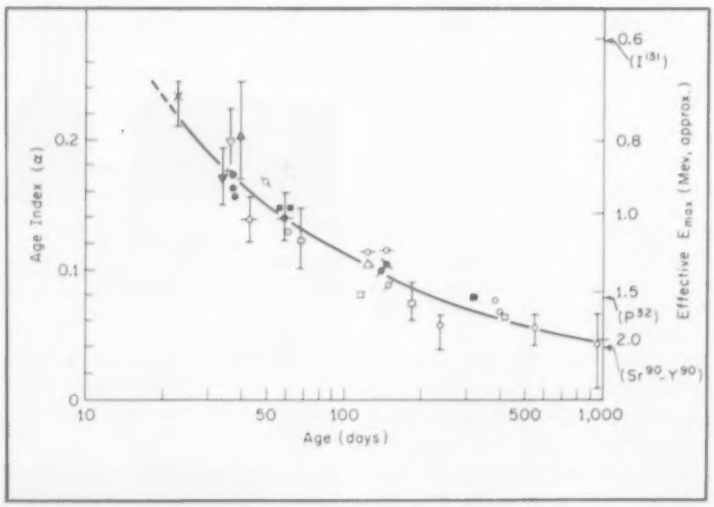
To date a nuclear explosion, radioactive-decay curves of the fallout products are generally used (*1–4*). However, all methods based on decay have the common drawback of requiring times of the order of at least 1 week to be applied successfully. A more rapid method of dating should therefore be based on other physical properties of the fission products.

We have investigated the possibility of using the continuous change in β-ray energy distribution as manifested in β-absorption curves of fallout products.

Preliminary experiments have shown that the most time-sensitive portion of the absorption curve is located at its beginning. We chose the absorber range 10–30 mg/cm² as the basis for "age" comparison. This choice, though somewhat arbitrary, is not unimportant from the point of view of statistical accuracy. If I_{10} and I_{30} are the counting rates at 10 and 30 mg/cm², the difference $\alpha \equiv \log I_{10} - \log I_{30}$ is the most directly useful index of age for dating purposes.

Measurements

Radioactive samples were obtained from atmospheric precipitations in Istanbul and Uludağ (1,900 meters above sea level) by filtration through cotton. After drying, the cotton was burnt, and the residual ash was collected in 17-mm-diameter standardized cardboard trays protected by thin homogeneous paper covers (1.4 mg/cm²). After 2 days for allowing the natural radioactivities (thoron and radon daughter products) to decay to negligible levels, the β-absorption curves were measured with an end-window counter in a 4-in. lead shield using aluminum absorbers up to 50–80 mg/cm².



AGE INDEX for 16 differently aged fallout samples during 1954–56. Sample age is from date of atomic explosion to day of measurement. Symbols are repeated where more than one measurement made on sample. Energy scale indicates how effective E_{max} of fallout products increases with time; this scale is obtained from absorption measurements of several radioisotopes under same experimental arrangement used for fallout samples

In these absorber ranges low-energy β particles play a significant role. Tests were carried out using several β emitters with different E_{max}, and with different geometries, backings and source thicknesses to evaluate the effects on α (*5*). All parameters but the source thickness could be kept constant in measurements. Some error, though not more than ~4%, may have been introduced systematically in this way. The probable errors of the individual measurements were higher, of the order of 10%, due to the low source strengths available.

Results

The illustration shows α as a function of age for sixteen different samples that were collected during 1954–56. Only those samples for which the age was fairly accurately known are used. Official announcements and our dating method (*2*) based on decay were used for this purpose. Some samples could be measured more than once, the indices of the same sample being shown by the same sign on the figure. Although a nuclear explosion as far away as Nevada can cause radioactive precipitations here 5–8 days after its occurrence (*2*), a prompt atmospheric transportation of that kind did not happen to occur during the present period of observations. The shortest age was 20 days after the Russian tests of November 23, 1955.

Conclusion

In spite of the somewhat large scattering of the experimental points, the absorption method of dating nuclear explosions appears feasible. If no natural radioactive products are present in a fallout sample, the dating of the corresponding nuclear explosion is reduced to a matter of a few hours.

The accuracy attainable with the new method is probably limited only by the accuracy with which the age index is measured. For our rather weak samples this was low. The ultimate shape of the age-index curve may therefore undergo some slight changes if one is able to work with stronger samples.

BIBLIOGRAPHY

1. Norman J. Holter, Wilford R. Glasscock, NUCLEONICS **10**, No. 8, 10 (1952)
2. Sait Akpinar, Remziye Akpinar, *Rev. Fac. Sci. Univ. Istanbul, Series C* **20**, 287 (1955)
3. F. Yamasaki, H. Kaneko, *J. Sci. Research Inst. (Tokyo)* **49**, 137 (1955)
4. O. Haxel, G. Schumann, *Naturwiss.* **40**, 458 (1953)
5. For similar experiments see: "Radiochemical Studies: The Fission Products," National Nuclear Energy Series IV-9, Book 1 (McGraw-Hill Book Co., Inc., New York, 1951)

Can you identify these alchemy symbols?

METALS FOR THE ATOMIC AGE

The Atomic Age is an age of metals—old metals that find new uses in new surroundings—rare and little-known metals.

Old or new, rare in occurrence or use, these metals may be light, heavy, hard or soft. Their use as fuels, or in the structure or controls of nuclear reactors will vastly increase the use of all our metal resources

Vitro is at the heart of metals development for the Atomic Age, both in new processes and uses for old metals, and the mining and refining of new, rare metals. Through its divisions and associated companies, Vitro mines and refines fissile uranium and fertile thorium. Through its research and development activities, Vitro is attacking the production of old, known metals like manganese and boron by new and unconventional processes. New metals like columbium and tantalum are being recovered and rare earth metals like europium, gadolinium, yttrium and samarium are being mined and recovered.

In these activities, Vitro geologists work as a team with Vitro scientists and engineers to seek new deposits of these metals—and to find new means to coax them from obscurity into profitable use in the Atomic Age.

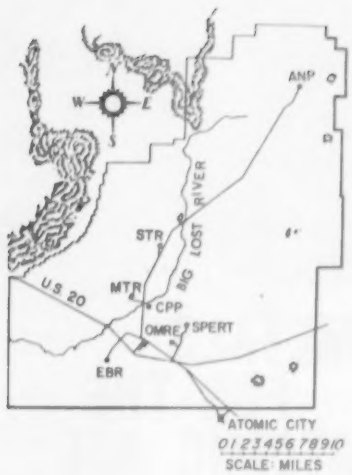
Vitro

CORPORATION of AMERICA
261 Madison Ave., New York 16, N.Y.

Research, development, weapons systems
Nuclear and process engineering, design
Refinery engineering, design, construction
Uranium mining, milling, and processing
Thorium, rare earths, and heavy minerals
Recovery of rare metals and fine chemicals
Aircraft components and ordnance systems
Ceramic colors, pigments, and chemicals

1. Gold *2. Lead* *3. Tin* *4. Copper* *5. Silver* *6. Iron*

Reactors Dot Idaho Desert at National Reactor Testing Station



PROPULSION, power-generating, and testing reactors and auxiliary facilities constitute the broad research program at the National Reactor Testing Station near Idaho Falls, Idaho. Here, because of the isolation afforded by the vast desert expanse, new reactor types are being tested.

Five major contractors operate NRTS facilities:

Argonne National Laboratory projects are the experimental breeder reactors (EBR-I, to operate with new core in late '57; EBR-II, to go critical in '60), the boiling reactor experiment (Borax-IV), zero-power critical assembly (ZPR-III) and the Argonne low-power reactor (military prototype, under construction).

Atomics International will have the organic-moderated reactor (OMRE) operating by fall '57.

General Electric is conducting the aircraft nuclear propulsion program.

Phillips Petroleum operates the Materials Testing Reactor (MTR), the gamma-irradiation facility and the chemical processing plant (CPP). It is conducting the special power excursion reactor tests (SPERT-I; -II, being designed; -III, under construction). Phillips will begin operating the engineering test reactor (ETR) in late '57.

Westinghouse projects are the S1W (Nautilus prototype), the A1W (large ship reactor prototype, under construction) and the expended-core facility (in design stage), for dismantling expended cores.

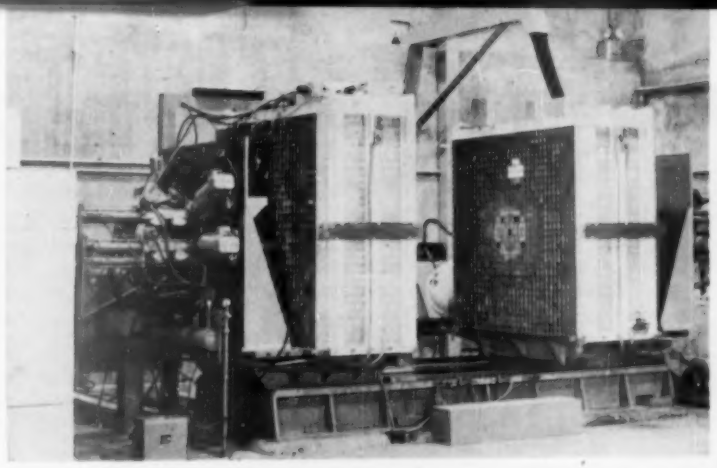
In addition, Aerojet-General is conducting its gas-cooled-reactor experiment, now in the preliminary design stage, at NRTS.

ANP Area

NRTS was selected in 1952 as the test site for aircraft nuclear power plants. To date, all the aircraft nu-

SPERT program (special power excursion reactor test), part of AEC reactor safety studies, provides information on water-cooled reactors. Above are control rod drives of SPERT-I; SPERT-II and -III will carry tests up to 2,500 lb/in² and 670° F

EBR (experimental breeder reactor) program is for studying breeding process. At right is EBR-I (200 kw electricity), which demonstrated feasibility of breeding; in foreground are fuel-handling cave and transfer coffin. Construction will start this summer on EBR-II



ZPR-III (zero power reactor) is used to build mockups of fast-reactor cores to make critical measurements. Current investigation is of EBR-I core; next will be mockup of EBR-II

CPP (chemical processing plant) recovers U^{235} from spent fuel; recovery is >99%. In addition to being a producing plant, CPP serves as pilot plant. Below are controls for batch dissolution

clear propulsion facilities at NRTS, totaling $15,000,000, have been funded by the AEC.

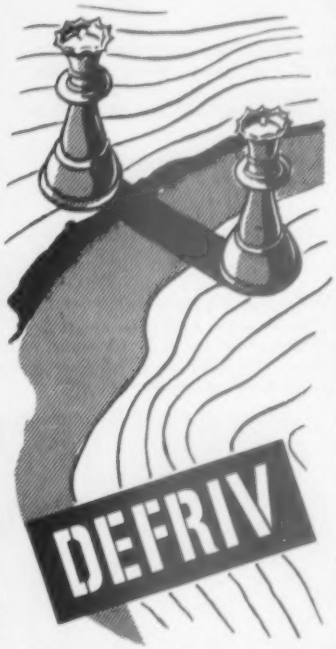
The assembly and maintenance building is within a 15-ft-high earth embankment. In this building is a hot cell for remote power-plant assembly work.

An area for testing power plants consists of a test pad that can be enclosed with a moveable aluminum building and an underground control and equipment room. A flight engine test facility costing $6–7,000,000 is to be completed in 1959; here, nuclear engines will be tested in conjunction with airframes, crew compartments and aircraft control systems.

A low-power test facility is scheduled for completion by 1958.

GAMMA IRRADIATION FACILITY uses spent MTR fuel elements to give fields up to 2×10^7 r/hr. Irradiation services are available to public. Potatoes and cans are shown being put into columns containing demineralized water

OMRE will test diphenyl or triphenyl as moderator-coolant. Construction is essentially complete; operation is scheduled for late '57. Below is reactor housing, pipes at right lead to air-blast heat exchanger



Defriv: a simulated map war game involving defensive operations along a river line under conditions of simulated atomic warfare. Map battles, fought by groups of field-experienced officers, evaluated by a team of scientists and officers, improve our Army's ability to wage modern war—a typical example of the work of Combat Operations Research Group.

▶ **PHYSICISTS**

▶ **MATHEMATICIANS**

▶ *and other* **SCIENTISTS**

will find in CORG a small but growing research group, with freedom to think and limitless creative opportunity. Varied scientific disciplines, good living conditions, and all usual benefits, make CORG a "good place to work." Find out for yourself.

Address: ROBERT L. KOLLER
Operations Research Group

tech ops

TECHNICAL OPERATIONS, INCORPORATED
Burlington, Massachusetts

NUCLEAR ENGINEERING NOTES

New Containment Strategy

A new strategy for reducing containment shell pressure after an accident involves the use of large bodies of water stored within the shell to limit the temperature rise for a given energy release. The idea came from work done by Sargent and Lundy on the design of the containment shell for the Experimental Boiling Water Reactor (EBWR) at Argonne National Lab. and was described by A. Kolflat at the March meeting of the American Power Conference.

To determine the internal pressure and shell-wall temperature gradient that would result from an accidental rupture of any part of the power plant, specified amounts of boiling water under pressure were injected into a large steel tank that was a mockup of the EBWR containment shell.

The internal pressure and temperature gradient in the wall were observed in these experiments to reach their maximum values about 6 sec after the addition of the boiling water. The temperature gradient amounted to something like 50° F across the $\frac{3}{16}$-in. shell wall.

Investigators found that the maximum value of internal pressure was quite sensitive to the amount of heat absorbed by structural material contained in the shell and by the shell itself. For instance, by extrapolating their results, they predicted a pressure of about 6 psig for a similar situation in EBWR.* If no heat were absorbed by the structural material, this pressure would increase to 15 psig.

Kolflat suggested that the maximum pressure to be contained by the shell (and, therefore, the cost of the shell) could be reduced by installing heat-absorbing media inside the shell. He proposed a design in which the reactor structure would be surrounded by a large amount of water contained in trays or thin-walled cans. The emergency spray system presently incorporated in the EBWR containment design is a modification of this idea. A 15,000-gal tank located just inside the top of the shell dome will supply water to be sprayed into all parts of the shell to condense any steam that may be released.

* The total thermal energy available in the water was arbitrarily doubled to account for possible chemical energy release.

SEVENTY-FIVE TON ROTATING SHIELD of Sodium Reactor Experiment (SRE) being lowered into concrete floor above core tank. Some 140 in. in diameter, it contains stepped tubes for 81 small plugs to provide access to each core channel and three large plugs to provide access to canned graphite moderator assemblies. Shield is rotated to bring large plugs over assemblies to be removed. Stepped stainless-steel shield casing is filled with concrete. Skirt around bottom covers thermal insulation consisting of 13 thin stainless-steel plates. SRE went critical April 25

. . . . . deeper into the microcosm

Pulsed Neutron Generator . . $22,500

Brower Multiple Scattering Microscope . . . $5,500

16 sq. ft. Diffusion Cloud Chamber . . . $7,000

Sub-critical Training Reactor . . . (In association with Neutronic Consulting & Design)

A L

ATOMIC
LABORATORIES, Inc.

3086 Claremont Avenue

Berkeley 5, California

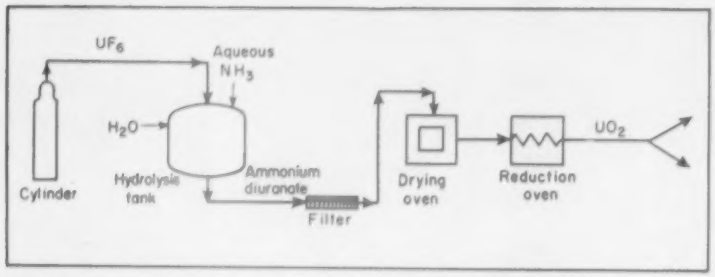


FIG. 1. Uranium dioxide enriched in U^{235} made in this manner is satisfactory raw material for cold compacted and sintered pellets or for high-fired cermet-type fuel elements (1)

Steps in Preparing . . .

Uranium Dioxide for Fuel Elements

By H. H. HAUSNER
Nuclear Engineering Division
Penn-Texas Corp.
New York, New York

and

R. G. MILLS
Atomic Power Equipment Department
General Electric Co.
San Jose, California

The general development in the direction of high-temperature reactors brings with it considerable interest in so-called* ceramic materials, either alone or in combination with metals (cermets), for use in fuel elements operating at temperatures of 1,000° C or higher. While solid metallic fuels offer the advantages of good neutron economy, good thermal conductivity and high resistance to thermal shock, their phase changes and low strength at elevated temperatures hardly permit their use in high specific-power reactors. Ceramic fuel materials, on the other hand, offer the advantages of adequate strength at elevated temperatures, low thermal expansion, good corrosion resistance and stability against radiation damage.

A comparison between the melting temperatures of various compounds of uranium and other, more common, refractory materials (see Table 1) shows that UO_2 has the highest melting point of the possible ceramic fuel materials. Further examination of the physical properties of UO_2 (see Table 2) shows that this compound is chemically and thermally stable and, therefore, well suited to be used as a high-temperature nuclear fuel.

Production of UO_2 Powder

Uranium dioxide powder can be produced by several different methods, most of which use an aqueous uranyl nitrate solution as a raw material. With the addition of H_2O_2 to the solution, uranium peroxide is precipitated. The precipitate is converted to uranium trioxide by heating. If ammonia is added to the uranyl nitrate solution instead of H_2O_2, ammonium diuranate is precipitated, and this also can be thermally decomposed to uranium trioxide. The reduction of UO_3 to UO_2 can easily be accomplished in a hydrogen atmosphere.

The production of uranium dioxide enriched in the isotope U^{235} includes a gaseous-diffusion step with the uranium in the form of the hexafluoride, UF_6. This can then be converted to ammonium diuranate, and subsequently to any oxide desired (*1*).

The UF_6 process, worked out at Mallinckrodt Chemical Works in St. Louis, is shown in Fig. 1. Cylinders of UF_6 are heated by an electric blanket, with the fluoride compound vaporizing through pig-tail pipes into a water tank. In water, UF_6 rapidly hydrolyzes into HF and uranyl fluoride (UO_2F_2). The uranium then precipitates as ammonium diuranate when aqueous ammonia (25–30%) is added in the hydrolysis tank. After the compound is filtered, washed and dried, it is decomposed to U_3O_8 with steam. When the U_3O_8 has

* In the generally accepted, strictest meaning of the word, metallic oxides such as UO_2 are not ceramics but refractories. Ceramics, normally speaking, are materials whose main ingredient is clay, whereas refractories are substances that are *unaffected by high temperatures*. The difference is obvious, but we bow to current usage—UO_2 is called a ceramic in this article.

TABLE 1—Melting Points for Comparison

Possible "ceramic" fuels		*Common refractories*	
Material	*Melting point (° C)*	*Material*	*Melting point (° C)*
US	1,700	Silica (SiO_2)	1,710
USi	1,700	Fireclay	1,750
US_2	1,850	Alumina (Al_2O_3)	2,020
UC_2	2,700	Zirconia (ZrO_2)	2,700
UO_2	2,800	Magnesia (MgO)	2,800

TABLE 2—Properties of Uranium Dioxide

*Property**	*Temperature (° C)*	*Value*	*Bibliography reference**
Melting point	2,405 ± 21		(4)
	2,878 ± 22		(63)
Thermal conductivity† (cal/sec/° C/cm)	200	0.0190	(61)
	400	0.0138	
	600	0.01055	
	800	0.00885	
	1,000	0.00815	
Heat capacity‡ (cal/gm/° C)	100	0.063	(60)
	200	0.067	
	500	0.074	
	1,000	0.078	
	1,500	0.082	
Heat of formation (cal/mole)	25–1,200	−259,500 ± 2,000	(20)
Free energy of formation (cal/mole)	25	−246,600	(20)
	727	−218,100	
	1,227	−197,700	
Heat of fusion (cal/mole)	2,405	16,000	
Heat of vaporization (cal/mole)		137,000	(60)
Entropy (cal/mole/° C)	25	18.6	(60)
Vapor pressure§ (mm of Hg)	1,326	1.65×10^{-8}	(4)
	1,702	6.67×10^{-8}	
	2,126	4.21×10^{-2}	
	2,363	9.66×10^{-1}	
Coefficient of linear expansion¶ (cm/cm/° C)	27–400	9.1×10^{6}	(17)
	400–800	10.8×10^{6}	
	800–1,260	13.0×10^{6}	
Theoretical density (gm/cm³)	26	10.968	(64)
Lattice constant‖ (Å)	26	5.4682	(64)
Young's modulus of elasticity (psi)	20	25×10^{6}	(53)
Modulus of rupture (psi)	25	10,000–12,000	(17)
Thermal neutron absorption cross section (cm²/cm³)		0.165	(53)
Tammann temperature (° C)	~1,150		(10)

* Many of the properties listed in the table are dependent on the powder particle size, on the porosity and on the impurity content. The original references should be consulted for these details; see bibliography at end of article.

† Thermal conductivity (61) was determined on samples of 73% theoretical density; data listed here are extrapolated to 100% dense specimens as a direct function of density. The thermal conductivity of uranium dioxide decreases with increasing temperature, which is characteristic of inorganic oxides.

‡ Preliminary work at the Oak Ridge National Laboratory has indicated a discontinuity in the curve of heat capacity vs. temperature in the region of 400–600° C. This is still under investigation (A. J. Taylor, personal communication).

§ Vapor-pressure data given by Ackerman (4) can be fitted with a curve whose equation in the range of 1,600–2,700° K is

$$\log p = 13.340 - \frac{3.7337 \times 10^{4}}{T} + \frac{3.6700 \times 10^{6}}{T^{2}} + \frac{2.4638 \times 10^{9}}{T^{3}}$$

where T is the absolute temperature in degrees Kelvin.

¶ The coefficient of linear expansion data can be fitted with a curve whose equation in the range of 27–1,260° C is (17)

$$Y = at^{2} + bt + c$$

where Y = thermal expansion (%) based on length at 27° C
t = temperature (° C)
$a = 2.1481 \times 10^{-7}$
$b = 8.4217 \times 10^{-4}$
$c = 3.0289 \times 10^{-2}$

‖ The crystallographic lattice constant is reported (4) to decrease with increasing oxygen content above $UO_{2.00}$, which is contrary to what would normally be expected.

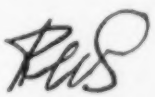
MEMORANDUM:

From the Desk of the President

To: Purchasing Department

* * *

Investigate Davison's entry into the thorium and rare earths field. Understand they are producing materials which should be of interest to us. They have a reputation for dependability of products and service.



Two plants, one at Pompton Plains, N. J. (formerly Rare Earths, Inc.) and one at Baltimore, Md. are in operation. Your inquiries concerning products, samples and research and development services are welcome.

Progress Through Chemistry

DAVISON CHEMICAL COMPANY

Division of W. R. Grace & Co.

Baltimore 3, Md. and Pompton Plains, N. J.

HORIZONS *unlimited*

Today, Martin activities and facilities in the field of nuclear research and development are among the most advanced in the aircraft industry.

Result: Never before have there been comparable opportunities at the frontier of a new and horizonless science.

If you are interested in packaged power systems development, the limitless field of radiation chemistry, or fundamental research in nuclear power, you would be wise to investigate the Martin story.

Contact J. J. Holley, Dept. N-7, The Martin Company, Baltimore 3, Maryland.

MARTIN
BALTIMORE

been dried, it is reduced with hydrogen at high temperatures to UO_2.

The bulk density and particle size of the resultant UO_2 depend on the density and particle size of the parent material. The temperature of reduction of the parent material likewise influences both the crystallite size and particle size of the UO_2. Figure 2 shows this correlation and indicates that the higher the temperature of reduction, the greater will be the resultant crystallite size of the UO_2 (*10*).*

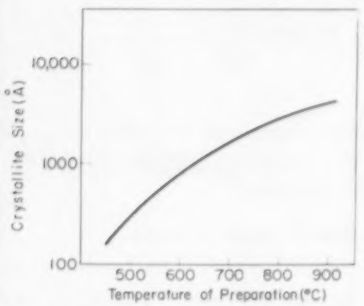


FIG. 2. Particle size of UO_2 depends on the temperature of reduction from higher oxide (10)

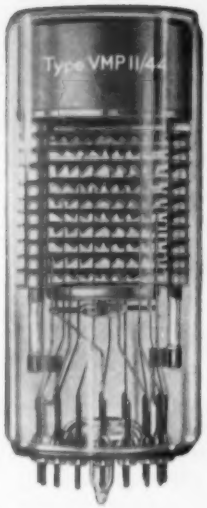
The uranium dioxide powder thus produced can be used for nuclear fuel in a variety of shapes and forms: (a) as high-density compact, casting or extrusion in the shape of slugs, rods or tubes; (b) as fine powder uniformly dispersed in Al, Zr or SS; (c) as small Al-, Zr-, or SS-clad pellets; and (d) as a solution in concentrated $H_4P_2O_7$.

Fabrication by Powder Metallurgy

The fabrication of uranium dioxide powders into finished shapes can be accomplished by any of the conventional powder-metallurgy techniques. The UO_2 can be cold-compacted, either in a steel die or hydrostatically; it can be slip-cast, extruded or hot-pressed. The first three of these methods are normally followed by a sintering operation to obtain the desired density and strength.

Cold compacting. Uranium dioxide must be ball-milled to fine particles to be capable of being compacted and sintered to the desired high-density material. During ball milling in air, the uranium dioxide usually increases in oxide content. The increase in oxy-

* References are not sequential since they apply to the extensive alphabetical bibliography at the end of this article, p. 102.



PHOTOMULTIPLIERS OF HIGHEST EFFICIENCY

These tubes combine high sensitivity with exceptionally low noise and are therefore ideally suited to gamma spectroscopy as well as scintillation counting. The photocathode is formed on the flat end window and has highest sensitivity in the region of 4,200 A°. The range includes tubes having eleven or thirteen stages, Pyrex, kodial or quartz windows and cathodes of various diameters. The type illustrated has the following characteristics. Full details will be sent on request.

TYPE VMP. 11/44	
Cathode diameter	44 mm.
Minimum cathode sensitivity	30 μA/L
Average cathode sensitivity	50 μA/L
Spectral response	S 11
Minimum overall sensitivity at 160 v per stage	200 A/L
Average volts per stage for 200 A/L	135 v.
Maximum dark current at 200 A/L	0.1 μA
Anode capacity	8 ppf
Window material	Pyrex
Maximum diameter	51 mm.
Overall length (seated)	122 ± 1 mm
Base	B15B

20th CENTURY ELECTRONICS LIMITED

20th CENTURY ELECTRONICS LTD
CENTRONICS WORKS,
KING HENRY'S DRIVE,
NEW ADDINGTON, SURREY
ENGLAND

gen content depends largely on the ball-milling conditions and especially on the duration of the milling process. Prolonged ball milling results in the comminution of particles with an increased specific surface-area* and, therefore, greater oxygen pickup.

Very frequently a solid lubricant, such as stearic acid or polyethylene glycol, is blended into the powder before it enters the hopper. The blend is then fed from the hopper into the cavity of the die, in the lower end of which is a smooth-fitting punch. The amount of powder placed in the die is regulated by the position of the lower punch in the die cavity. After the hopper is withdrawn, the upper punch enters the die and compresses the powder. Compressing the powder in steel dies at pressures of 10,000–100,000 psi results in compacts with densities that depend on the particle size of the powder (see Fig. 3). Large parts can also be hydrostatically pressed in rubber molds at 30,000–45,000 psi.

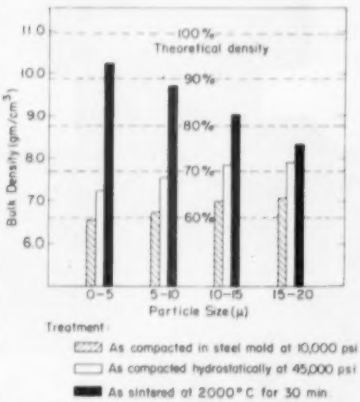


FIG. 3. Density of green compact (unsintered) ranges between 6 and 8.5 gm/cm³, depending on powder particle size—finer powders compact to lower densities than coarser ones (17)

When the compact is ejected from the die, it is strong enough to handle, but in this "green" state it is not yet usable. To acquire useful properties, it must be sintered.

Slip casting. Among the methods to be considered for fabrication of uranium dioxide fuel elements, slip casting offers a distinct advantage—it permits the production of fuel rods of any desired length and shape with a uniform density over the length of the element.

In this process, the slip, consisting of

* The specific surface is defined as the total surface area contained in 1 gm of powder and is usually expressed in cm².

WKNL IN THE NEWS

NUCLEAR MERCHANT SHIP

Walter Kidde Nuclear Laboratories has been awarded a contract by George G. Sharp, Inc., New York marine design firm, for nuclear consulting services in connection with the design of the first atomic-powered surface ship.

The design project was recently awarded by the U.S. Maritime Administration. Preliminary work will begin immediately.

Scope of the work includes nuclear shielding containment, ventilation, instrumentation and controls, and other items involved in the reactor system installation.

★ ★ ★

NUCLEAR REACTOR DEVELOPMENT

WKNL has received a contract to perform consulting services on the Pennsylvania Advanced Reactor project, a major development effort jointly sponsored by the Pennsylvania Power & Light Co. and Westinghouse Electric Corporation, leading to the design of an aqueous homogenous reactor plant having an electrical output of 150,000 kilowatts.

The services to be performed by WKNL include site survey and preliminary safety analysis, as well as extensions of WKNL studies initiated last fall on ventilation.

★ ★ ★

NUCLEAR BATTERY EXHIBIT

The miniature atomic battery developed jointly by Walter Kidde Nuclear Laboratories and Elgin National Watch Co. was exhibited at the International Trade Fair in Paris May 25 through June 10. The battery is also being shown at the Het Atoom, the educational section of the Amsterdam Trade Fair, during July and August.

Consultants to industry on applications of nuclear technology

WKNL

WALTER KIDDE NUCLEAR LABORATORIES, INC.

975 Stewart Ave., Garden City, N. Y.
Telephone Pioneer 1-4350

This aluminum casting is part of a missile fuel pump. Its 5/16" walls must pass a 1500 psi pressure test with no impregnation permitted. Interior walls are smooth and true as cast.

If your processing equipment requires parts with demanding metallurgical properties, close tolerances and intricacy, our unique foundry techniques may provide a solution. A number of demanding parts for nuclear and chemical applications have already been cast. Send for our illustrated technical booklet.

Morris Bean & Company
Yellow Springs 18, Ohio

porosity free castings!

BEAN

an aqueous suspension of finely ground UO_2, is poured into a plaster-of-paris mold. The plaster of paris absorbs the water from the slip, which solidifies and shrinks against the mold. The casting is then taken from the mold to be dried and sintered.

To prepare the slip, the finely ground powder is leached in concentrated HCl for several hours. The acid is then decanted and the process repeated three or four times. Next, the slip is washed until the proper *p*H value is obtained. The relationship between the *p*H value and the viscosity of the slip is shown in Fig. 4. Castings have been made with slips having the minimum viscosity that occurs at *p*H = 3.6, but the shrinkage is frequently not sufficient to permit the casting to be easily removed from the mold. Murray has suggested (*73*) using slips that have lower *p*H values. Inasmuch as the settling rate of an acid-leached slip is not too high, castings can be satisfactorily made at *p*H values of 1.5–2.0.

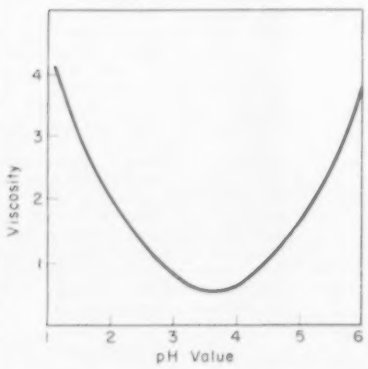


FIG. 4. Curve shows relationship between pH value and viscosity of UO_2 slip

To improve the strength of the UO_2 casting, organic dispersion agents should be added to the slip before it is poured into the mold. Organic materials such as polyethylene glycol not only improve the strength of the green casting but also prevent cracking by slowing down the rate of water removal by the plaster mold. This permits the casting of fairly thin tubular shapes (*19*).

Before it is sintered, the green casting is dried slowly (up to several days) at room temperature. Slip-cast parts require a prolonged sintering time at fairly high temperatures. The furnace temperature must be slowly raised to 600° C and kept at this temperature for several hours to permit the organic dispersion agent to vaporize. The fur-

nace temperature is then raised to 1,700° C, or even up to 2,000° C.

Extrusion. The extrusion method should be used to fabricate parts that have a large length-to-diameter ratio. Such parts cannot be compacted by conventional cold-pressing techniques without serious density gradations along the major axis.

The extrusion of uranium dioxide can be accomplished only if the material is very finely ground, and if a plasticizer is added to the mix. The plasticizer is usually a liquid with a high boiling point and low volatility at ordinary temperatures. It is compounded with the UO_2 powder to increase moldability. It also decreases the abrasive action of the powder on the die surfaces, but since the use of a plasticizer decreases strength, a compromise must be effected, and dies with extremely hard surfaces must be used. The majority of plasticizers are esters of organic acids.

The extruded material should be of regular cross section to avoid trouble with differential shrinkages during sintering.

Sintering. The powder particles, which have been pressed into intimate contact by any of the processes described previously, actually diffuse into each other during sintering, so that the compact, casting or extrusion approaches true solidity. However, true solidity is almost never attained, nor is it necessarily desired. Despite a lower density, the sintered compact will have good strength at high temperatures.

The rate of sintering for uranium dioxide powder compacts depends on the sintering temperature, the powder particle size and the excess oxide content of the compound. The sintering operation generally takes place at temperatures well below the melting point of the compound—usually between 1,600° C and 2,100° C. Small additions of TiO_2 permit sintering at about 200° C lower, if desirable.

We have said that UO_2 picks up oxygen when exposed to air. In powder form, it acquires this excess oxide content even when stored in glass containers. Since it is impracticable to keep UO_2 in an oxygen-free environment, particularly during compacting, some increase in oxide content is unavoidable. Table 3 shows that the amount of increase is dependent in part on the particle size and on the time of exposure (*10*). The fact that UO_2 picks up oxygen when exposed to air is frequently overlooked but is of

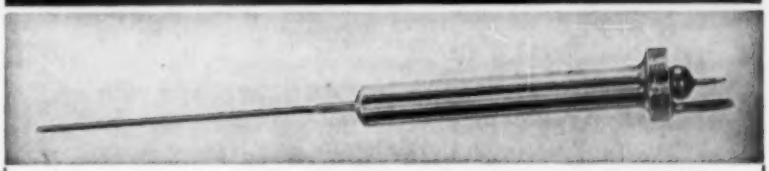
HOKE announces

10 valves in 1

360 SERIES
High Pressure
UNION BONNET
GLOBE VALVE

For conditions ranging from 3000 psi to low vacuums, or distilled water to corrosive fluids. Series consists of four basic stainless steel bar stock valves...O-ring or Teflon packing with flat Teflon disc or vee point non-rotating, replaceable stem plug... plus six body styles. All parts interchangeable as well as replaceable. Choice of ¼", ⅜" or ½" pipe sizes or Swagelock tube fittings. Panel mounting, too. Get the facts about this "10 in 1" valve. Write us today.

HOKE
HOKE INCORPORATED
Fluid Control Specialists
235 S. Dean Street
Englewood, N. J.



Lelab metal-walled G-M tubes for anti-coincidence applications—where uniformity counts!

Except for a glass bead insulator, Lelab Counter Tubes are constructed entirely of metal. The metal cylinder is used both as the envelope and the cathode.

The restriction of all component parts within the diameter of the tube permits close stacking. Each counter is custom-built, filled, and tested in order to insure stability and uniformity.

LELAB PROBE COUNTER TUBE FOR NEUROSURGERY

(Robinson-Selverstone Type)

Made especially for neurological surgery and other purposes requiring a miniature probe tube. The small needle-like probe provides an ideal way of measuring radioactivity *in vivo* and for probing small areas with a relatively strong field intensity.

Write for complete information

H. W. LEIGHTON LABORATORIES, York & Sunset Lane, Hatboro, Pa.

Scientists . . . Engineers

. . . look to Westinghouse

Commercial Atomic Power

CAPA—Commercial Atomic Power Activity—is the nucleus of the most dynamic new division at Westinghouse, the leader in Atomic Power. Our growth is bound to be *steep*—as electric power demand and atomic power production pyramid sharply.

We're "fluid"—not fixed. New supervisory jobs open up fast! We're entirely *commercial*—not dependent on government contracts. Opportunities for advanced study at company expense. Get in on the "industry of tomorrow" *today* . . . at Westinghouse CAPA.

Immediate Openings for professionally established men and those just starting their careers: Physicists • Physical Chemists • Chemical Engineers • Mechanical Engineers • Electrical Engineers • Designers • Metallurgists.

Send your résumé

Please mail résumé of your professional and business background to: C. S. Southard, Westinghouse Commercial Atomic Power, Box 355, Dept. 146, Pittsburgh 30, Pennsylvania.

WESTINGHOUSE

FIRST IN ATOMIC POWER

TABLE 3—Increase in Oxygen Content of UO_2

Prepared from	*Particle mean diameter* (μ)	*Exposure time (room temp.)*	*Analysis value of x in* UO_{2+x}
U_3O_8	0.38	1 month	0.022
"	1.3	2 days	0.012
"	1.36	3 days	0.005
"	0.56	~3 days	0.012
UO_3	0.45	2 days	0.006
"	0.059	1 day	0.135

extreme importance in its effect on the sintering process.

The effect of particle size on the bulk density after sintering at 2,000° C for 30 min can be seen by referring back to Fig. 3. The fine powder particles, which compact to a low density, sinter to considerably higher densities than the coarse powders that compact so well. Densities of 10 gm/cm³ or higher can be achieved by close correlation of sintering temperatures and sintering time (*55*).

The sintering of uranium dioxide compacts should occur in a hydrogen or inert atmosphere. Sintering in air is not recommended because it would result in the reaction

$$UO_2 \rightarrow U_3O_8 \rightarrow UO_2$$

with a corresponding change in density from

$$11 \rightarrow 8.4 \rightarrow 11 \text{ gm/cm}^3$$

This kind of density change would result in a complete fracture of the compact during sintering.

The uranium dioxide compacts lose as much as 1% of their weight during sintering. This weight loss usually depends on the following variables: (a) the oxygen content of the powder, (b) the powder particle size, (c) the amount of lubricant or plasticizer in the compact, and (d) the compacting pressure. Figure 5 shows this weight loss as a function of the amount of oxygen in the oxide. During sintering the amount of oxygen above the stoichiometric composition will be freed, thus lowering the weight of the compact. During the decomposition of UO_{2+x} to $UO_{2.0}$, the atoms are in a state of great mobility and contribute therefore to a higher rate of diffusion, which then results in a more rapid sintering or sintering to a higher density. This

process can be considered as a kind of "activated" sintering.

The amount of weight lost during sintering is a function of grinding time. Prolonged grinding results in finer particles with an increased ratio of surface area to volume. The greater the specific surface of the powder, the greater the decomposition during sintering and the greater, therefore, the weight lost.

The amount of lubricant or plasticizer in the compact also has its effect on the weight lost during sintering. Frequently, sintering furnaces are constructed that have a preheat chamber through which the parts pass before reaching the sintering zone. The preheating evaporates the lubricant or plasticizer added during blending

There is also a correlation between compacting pressure and the weight lost; however, this correlation is not too well understood as yet. The UO_2 particles are nonplastic and therefore

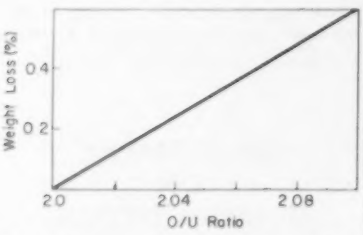


FIG. 5. Curve shows weight lost during sintering of UO_2 compact and its correlation with amount of oxygen in oxide

rearrange and compact to a greater density with increasing compacting pressure. One may assume that with greater compacting pressure less surface area of the particles is exposed, and therefore the weight lost should decrease as compacting pressure increases. This assumption, however, is probably not entirely correct. We may just as readily assume that a large number of these particles will fracture and break into smaller particles as compacting pressure increases. The increased total surface area thus produced should result in an increase in the amount of weight lost as compacting pressure increases.

Cladding

To prevent fission gases from contaminating the coolant, the fabricated uranium oxide parts have to be clad. Several cladding materials are presently under consideration. These include aluminum, stainless steel and Zircaloy. The selection of a cladding

Rare Earths have remained rare only because of the exceptional technology required to process them. The best of this technology is everywhere evident in HEAVY MINERALS CO.'s new Chattanooga plant, now on stream.

Using domestic ores from its own mines, HEAVY MINERALS produces a complete line of rare earths for American industry.

The rare earths constitute a new industrial frontier. These 15 elements plus yttrium and thorium have so many versatile properties that almost all industries have a potential use for one or more of them.

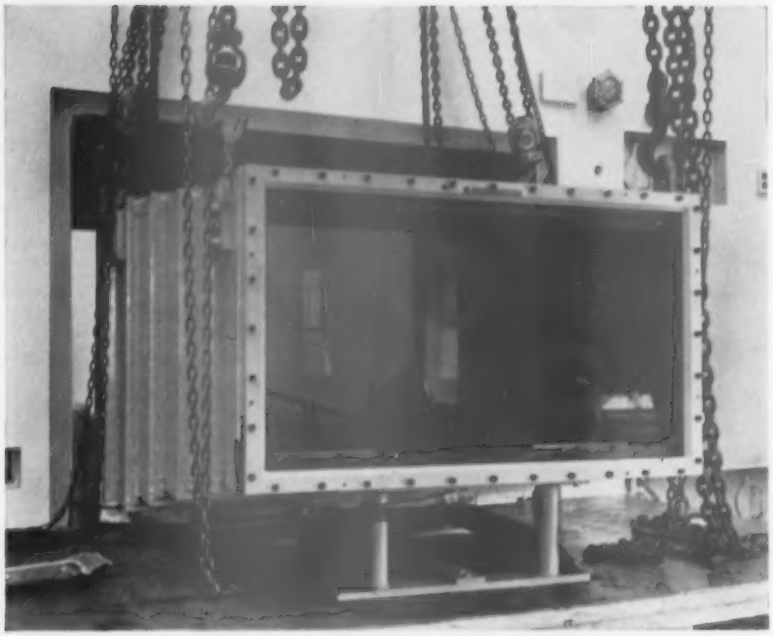
HEAVY MINERALS supports its processing operations with a vigorous research and development program. Its personnel welcomes the chance to share its technology with rare earth users and potential users. We invite you to make use of our services and products.

Send for free informative booklet

HEAVY MINERALS CO.

RARE EARTH CHEMICALS • THORIUM • HEAVY MINERALS

4000 NORTH HAWTHORNE STREET, CHATTANOOGA 8, TENN.
SALES OFFICE: 261 MADISON AVENUE, NEW YORK 16, N. Y.



This 60-inch Corning window came to Sinclair Research Laboratories completely assembled and ready to install.

You leave a hole in the hot cell... we'll do the rest

One of the most vital parts of your cell—a window to see through—can be the least of your worries.

Just tell us the wall thickness and energy level you're working with and the viewing area you want.

Then leave the rest to us.

We provide *all* calculations, designs and materials, and deliver a packaged window that is ready to install.

Your window will be designed specifically to meet the conditions you outline.

It will use one, two, or all three of these glasses developed by Corning for radiation shielding:

Corning Code 8362—Cerium-stabilized, non-browning lead glass. Density—3.3 gm. per cc. Equals dense concrete for shielding. Refractive Index—1.59.

Corning Code 8363—Special, high-lead glass. Density—6.2 gm. per cc. Equals iron's shielding protection. Refractive Index—1.98.

Corning Code 8365—Cerium stabilized, non-browning lime glass. Density—2.7 gm. per cc. Refractive Index—1.52.

Whether dry or oil-filled, the glass windows are resistant to corrosion and moisture. They do not decompose or darken under radiation.

One measure of their success is the fact that there are more than 250 Corning windows in use throughout the country, ranging up to 60 inches in thickness.

For complete details on the glasses, the windows, and the services you can get from Corning, write for a copy of Bulletin PE-51.

CORNING GLASS WORKS
16-7 Crystal Street, Corning, N.Y.
Corning means research in Glass

metal is governed by the type of coolant and the operating temperature.

Heat transfer from the fuel to the cladding material can occur either through a direct bond or through an intermediate medium such as inert gas. In any cladding problem, the relative thermal expansion between fuel and cladding must be considered. Neither aluminum, stainless steel nor Zircaloy has the same coefficients of thermal expansion as uranium dioxide—those of aluminum and stainless steel are greater and that of Zircaloy is smaller than UO_2. The greater expansion of the cladding metal, however, does not matter mechanically if a liquid metal or gas is used as the heat transfer media between fuel and cladding. These materials would accommodate any volume changes. No matter what the heat transfer media, Zircaloy cladding has to be carefully applied in such a way that the differential between the coefficients of expansion results in a direct contact between fuel and cladding at operating temperature without exerting any considerable stresses in either the fuel or the cladding.

BIBLIOGRAPHY ON URANIUM DIOXIDE

1. Peaceful atom also plentiful, *Chem. Eng. News* **34,** No. 44, 5320 (1956)
2. Acid cure: a new process for U_3O_8 at Shiprock, *Mining World* **17,** No. 8, 46 (1955)
3. B. M. Abraham, H. E. Flotow. Some characteristics of UO_2 NaK slurry (Am. Nuclear Soc., Chicago, June, 1956)
4. R. J. Ackerman. The high temperature, high vacuum vaporization and thermodynamic properties of uranium dioxide, ANL-5482 (1955)
5. K. B. Alberman, J. S. Anderson. The oxides of uranium, *J. Chem. Soc.*, **1949,** 8303 (1949)
6. K. B. Alberman, J. S. Anderson, J. Blakey. The binary system UO_3-CaO, *J. Chem. Soc.*, **1951,** 1352 (1951)
7. R. E. Allen (Comp.). Uranium and its compounds: a bibliography of unclassified literature, TID-3041 (1953)
8. J. S. Anderson, et al. The oxides of uranium. Part III. UO_3-MgO-O, *J. Chem. Soc.*, **1953,** 1731 (1953)
9. J. S. Anderson, et al. The oxides of uranium. Part IV. UO_3-ThO_2-O, *J. Chem. Soc.*, **1954,** 3324 (1954)
10. J. S. Anderson, et al. The properties and microstructure of uranium dioxide; their dependence upon the mode of preparation, AERE-C/R 886 (1955)
11. J. S. Anderson. Recent work on the chemistry of uranium oxides, *Bull. Soc. Chim. France* **1953,** 781 (1953) (AEC-tr-2065)
12. R. J. Beaver. Irradiation experiment on uranium dioxide-aluminum powder fuel plates, CF-55-6-13 (1955)
13. W. Biltz, H. Mueller. Contributions to the systematic study of species. XLI. On uranium oxide, *Z. anorg. u. allgem. Chem.* **163,** 257 (1927) (UCRL-Trans-43)
14. J. S. Boegli, R. G. Deissler. Measured effective thermal conductivity of uranium oxide powder in various gases and gas mixtures, NACA-RM-E-54L10 (1954)

BIBLIOGRAPHY ON URANIUM DIOXIDE (cont.)

15. A. Boulle, et al. On uranium oxides of variable composition, *Compt. rend.* **233**, 1281 (1951)
16. B. I. Bozic, O. Gal. The reaction between gaseous hydrogen chloride and uranium oxide, U_3O_8, *Z. anorg. u. allgem. Chem.* **273**, 84 (1953)
17. M. D. Burdick, H. S. Parker. Effect of particle size on bulk density and strength properties of uranium dioxide specimens, *J. Am. Ceram. Soc.* **39**, No. 5, 181 (1956)
18. P. Chiotti. Experimental refractory bodies of high melting nitrides, carbides, and uranium, *J. Am. Ceram. Soc.* **35**, No. 5, 123 (1952)
19. R. E. Corwin, G. B. Eyerly. Preparation of refractories from uranium dioxide, AECD 3349; *J. Am. Ceram. Soc.* **36**, No. 4, 137 (1953)
20. J. P. Coughlin. Contributions to the data on theoretical metallurgy. XII. Heats and free energies of formation of inorganic oxides, *Bureau of Mines Bull.* 542 (1954)
21. J. W. C. Crawford. Fabrication of uranium oxide refractory vessels, Brit. Pat. 715,311 (9/15/54)
22. Fred E. Croxton. Uranium and its compounds. K-295, Part 2 (1951)
23. J. E. Cunningham, E. J. Boyle. MTR-type fuel elements, in "International Conference on the Peaceful Uses of Atomic Energy," vol. 9, p. 203 (United Nations, New York, 1956)
24. J. K. Dawson, M. W. Lister. Magneto chemistry of the heaviest elements. II. Oxides of uranium, *J. Chem. Soc.* **1950**, 2181 (1950)
25. H. deBryn, et al. The design of a small prototype of a homogeneous power reactor welded with uranium oxide suspension, in "International Conference on the Peaceful Uses of Atomic Energy," vol. 3, p. 116 (United Nations, New York, 1956)
26. H. deBryn, et al. A "dry" suspension of uranium oxide for a heterogeneous power reactor, in "International Conference on the Peaceful Uses of Atomic Energy," vol. 3, p. 121 (United Nations, New York, 1956)
27. J. W. Droege, et al. Solubility of uranium in fused hydroxides, BMI-928 (1955)
28. C. S. Eian, R. G. Deissler. Effective thermal conductivities of magnesium oxide, stainless steel, and uranium oxide powders in various gases, NACA-RM-E-53G03 (1953)
29. C. Eichner, et al. Preparation of metallic uranium at the Bouchet plant of the commissariat of atomic energy, *Bull. soc. chim. France*, **1951**, 140 (1951)
30. L. F. Epstein, W. H. Howland. Binary mixtures of UO_2 and other oxides, *J. Am. Ceram. Soc.* **36**, No. 10, 334 (1953)
31. G. B. Eyerly, et al. Preparation of urania refractories, ANL-5038 (1953)
32. J. R. Findlay. The reaction between uranium trioxide and molten caustic soda. AERE-C/M-265 (1955)
33. O. Flint, et al. The anodic oxidation of uranium, *Acta Met.* **3**, 696 (1954)
34. E. R. Flook, R. G. Sweet. Oxidation of uranosic oxide to uranium-trioxide with nitric acid vapor, U. S. Pat. 2,735,745 (1956)
35. M. Freymann, et al. The Hertzian spectrum and the structure of solids. III. Preliminary investigations on nonstoichiometric uranium oxides, *J. phys. radium* **15**, 82 (1954)
36. D. M. Gillies. The reaction of hydrogen and oxygen with uranium oxides in water suspension, A-1262 (1955)
37. D. M. Gillies. Some studies of the reactions of uranium oxides with hydrogen, oxygen and water, MDDC-647 (1946)
38. D. M. Green. Absorption spectra and electrical conductivities of UO_2-ThO_2 solid solutions, *J. Am. Chem. Soc.* **76**, 2117 (1954)
39. F. H. Gunzel, Jr., W. A. Lambertson. Urania bodies; fired density vs. particle size, ANL-5094 (1954)
40. J. H. Handwerk, L. L. Abernethy. Urania and thoria bodies (Am. Ceram. Soc., New York, April, 1956)
41. R. K. Hart. An electron diffraction study of oxide films on uranium. *Trans. Faraday Soc.* **49**, 299 (1953)
42. H. H. Hausner, S. B. Roboff, "Materials For Nuclear Power Reactors" (Reinhold, New York, 1955)
43. H. Hering, P. Perio. Sur les equilibres des oxydes d'uranium entre UO_2 et U_3O_8, *Bull. soc. chim. France*, **1952** 351 (1952)
44. J. O. Hibbits, D. Zucker. The determination of adsorbed moisture on uranium and uranium oxide; a new method for moisture determinations, AECD-3535 (1953)
45. H. R. Hoekstra, J. J. Katz. Studies on the uranium oxygen system, AECD-2954 (1950)
46. H. R. Hoekstra, J. J. Katz. Direct determination of oxygen in Lewx familiar metal oxides, *Anal. Chem.* **25**, 1608 (1953)
47. H. R. Hoekstra, J. J. Katz. Determination of oxygen-uranium ratios in uranium compounds, AECD-3549 (1953)
48. H. R. Hoekstra, et al. The uranium-oxygen system: $UO_{2.8}$ to U_3O_8, *J. Phys. Chem.* **59**, 136 (1955)
49. H. R. Hoekstra, S. Siegel. Recent developments in the chemistry of the U-O system, in "International Conference on the Peaceful Uses of Atomic Energy," vol. 7, p. 394 (United Nations, New York, 1956)
50. F. Hund, G. Niessen. Anomalous mixed crystals in the ThO_2-UO_2 system. *Z. Elektrochem.* **56**, 972 (1952)
51. F. Hund, U. Peetz. Concerning additional fluorite phases in the mixed oxides of rare earths with uranium. Investigation of the systems: La_2O_3, Nd_2O_3, Sm_2O_3, Yb_2O_3, Sc_2O_3, with U_3O_8, *Z. anorg. u. allgem. Chem.* **271**, 6 (1952)
52. F. Hund, et al. Abnormal mixed crystals in the system cerium oxide-uranium oxide, *Z. Elektrochem.* **56**, 61 (1952)
53. J. R. Johnson. Ceramic fuel materials for nuclear reactors, (A.I.Ch.E., Nuclear Eng. and Sci. Congress, Dec. 1955)
54. J. R. Johnson, C. E. Curtis. The technology of UO_2 and ThO_2, in "International Conference on the Peaceful Uses of Atomic Energy," vol. 9, p. 169 (United Nations, New York, 1956)
55. J. R. Johnson, et al. The technology of uranium dioxide, a reactor material (Am. Ceram. Soc., New York, April 1956)
56. F. J. Johnston, et al. A study of uranium oxide behavior in water by O^{18} isotope exchange studies (Am. Nuclear Soc., Chicago, June 1956)
57. F. J. Johnston, et al. Behavior of uranium oxides in aqueous media (Am. Nuclear Society, Chicago, June 1956)
58. F. J. Johnston, et al. Dissolution of uranium oxide arising from slug failure, ANL-5084 (1955)
59. P. Jolibois. A new oxide of uranium, U_4O_7, *Compt. rend.* **224**, 1395 (1947) (AEC-tr-1951)
60. J. J. Katz, E. I. Rabinowitch, "The Chemistry of Uranium" (McGraw-Hill Book Co., Inc., New York, 1951)
61. W. D. Kingery, et al. Thermal conductivity: X. Data for several pure oxide materials corrected to zero porosity, *J. Am. Ceram. Soc.* **37**, No. 2, 107 (1954)
62. W. A. Lambertson. Refractory oxide melting points, AECD-3465 (1952)
63. W. A. Lambertson, M. H. Mueller. Uranium oxide phase equilibrium systems: I. UO_2-Al_2O_3, *J. Am. Ceram. Soc.* **36**, 329 (1953); II. UO_2-MgO, ibid., 332; III. UO_2-ZrO_2, ibid., 365; IV. UO_2-ThO_2, ibid., 397; V. UO_2-Nd_2O_3, VI. U_3O_8-MgO, VII. U_3O_8-TiO_2, ANL-5312 (1954)
64. S. M. Lang, et al. High temperature reactions of uranium dioxide with various metal oxides, NBS-C-568 (1956)
65. S. M. Lang. An annotated bibliography of selected references on the solid-state reactions of the uranium oxides, NBS-C-535 (1953)
66. A. Langer, C. Wilson. Contribution to the electroplating of uranium oxide on aluminum and magnesium, WAPD-RM-22 (1950)
67. C. E. Larson. Uranium trioxide, U. S. Pat. 2,723,181 (1955)
68. T. W. Leland. Physical properties of UO_2SO_4-D_2O solutions and ThO-H_2O slurries, CF-54-6-258 (1954)
69. A. Linz. Uranium oxide from ores, *Chem. Eng. Progress* **53**, No. 5, 205 (1956)
70. B. A. J. Lister, G. M. Gillies. The conversion of uranyl nitrate to uranium dioxide and uranium tetrafluoride in "Progress in Nuclear Energy" III, p. 19 (McGraw-Hill Book Co., Inc., New York, 1956)
71. L. R. McCreight, H. G. Sowman. Ceramics for nuclear power applications, *Bull. Am. Ceram. Soc.* **35**, No. 5, 176 (1956)
72. A. Magneli, L. Kihlborg. On the cerium dioxide-uranium dioxide system and cerium-uranium blue, *Acta Chem. Scand.* **5**, 578 (1951)
73. P. Murray. General interpretation of the pH-viscosity relationship for amphoteric ceramic oxide slips, AERE-M/R-507 (1950)
74. P. Murray, R. W. Thackray. The thermal expansion of sintered UO_2, AERE-M/M 22
75. P. Murray, et al. Practical and theoretical aspects of the hot pressing of refractory oxides, AERE-M/R8-93 (1952)
76. Precipitation of uranium oxide from alkali metal carbonate solutions, Brit. Pat. 716,595 (Oct. 1954)
77. D. W. Osborne, E. F. Westrum, Jr. The heat capacity of thorium dioxide from 10 to 350° K. The heat capacity anomalies in uranium dioxide and neptunium dioxide, *J. Chem. Phys.* **21**, 1884 (1953)
78. P. Perio. L'Oxydation de UO_2 à basse temperature, *Bull. soc. chim. France*, **1955**, 256 (1953) (AEC-tr-1952)
79. P. Perio. Crystalline varieties of UO_2, *Bull. soc. chim. France* **1953**, 776 (1953)
80. P. Perio. Observations on uranium oxides formed between UO_2 and U_3O_8, *Bull. soc. chim. France* **1953**, 840 (1953) (C. Demrick, trans., AEC-tr-2061)
81. M. J. Polissar. Activated uranium dioxide. U. S. Pat. 2,678,257 (1954)
82. W. G. Rauch. Urania-zirconium cermets, ANL-5268 (1954)
83. L. E. J. Roberts. The oxides of uranium. Part V. The chemisorption of oxygen on UO_2 and on UO_2-ThO_2 solid solutions, *J. Chem. Soc.* **1954**, No. 10, 3332 (1954)
84. L. E. J. Roberts, E. A. Harper. Determination of oxygen in uranium oxides, AERE-C/R 885 (1952)
85. W. Rudorff, G. Valet. On cerium-uranium blue and the semiconductive properties of the mixed crystal series UO_2-CeO_2, *Z. Naturforsch.* **7b**, 57 (1952)
86. W. Rudorff, G. Valet. On the cerium uranium blue and mixed crystals in the system CeO_2-UO_2-U_3O_8, *Z. anorg. u. allgem. Chem.* **271**, 257 (1953)
87. H. A. Saller. Phase relations in the U-Zr-O systems involving Zr and UO_2, BMI-1023 (1955)
88. M. H. Shackleford. Thermal conductivity of UO_2 powder, KAPL-M-MHS-23 (1954)
89. T. Shapiro, R. J. Clouse. Production of UO_2 by drying-calcining, K-1239 (1955)
90. M. Sisic. Dependence of the ratio O/U in uranium dioxide on the reduction temperature of UO_2, *Bull. Inst. Nuclear Sci.* **3**, 89 (1953)
91. S. Skorka. A method for the preparation of uranium oxide layers on aluminum, *Naturwissenschaften* **40**, 605 (1953)
92. E. Slowinski, N. Elliott. Lattice constants and magnetic susceptibilities of solid solutions of uranium and thorium dioxide, *Acta Cryst.* **5**, 768 (1952)
93. F. A. Smith, C. S. Lees. Electron microscope studies of particle size and shape in uranium oxide, AERE-G/M-136 (1952)
94. R. G. Sweet, Fluoride-free uranium oxide, U. S. Pat. 2,659,655 (1953)
95. G. Tridot. Peroxide compounds of uranium and molybdenum, *Ann. chim.* **10**, 225 (1955)
96. W. Trzebiatowski, P. W. Selwood. Magnetic susceptibilities of urania-thoria solid solutions, *J. Am. Chem. Soc.* **72**, 4504 (1950)
97. H. H. Van Tuyl. The determination of urano-uranic oxide in uranic oxide, HW-24700 (1952)
98. H. von Wartenberg, E. Prophet. Melting diagrams of refractory oxides. Part II. *Z. anorg. u. allgem. Chem.* **206**, 369 (1932); Part V. ibid., p. 369
99. J. T. Waber, J. A. O'Rourke. Oriented dioxide lms on uranium, AECD-3636 (1954)
100. C. Wagner. Thermodynamics of the system uranium-oxygen, to be published
101. J. M. Warde. Materials for nuclear power reactors, *Materials and Methods* **44**, No. 2, 121 (1956)
102. J. M. Warde, J. R. Johnson. Recent developments in the technology of ceramic materials for nuclear energy service, *J. Franklin Inst.* **260**, 455 (1955)
103. R. K. Willardson, et al. The electrical properties of uranium oxides, BMI-1135 (1956)
104. C. R. Wilson, A. Langer. Electrodeposition of uranium oxide on aluminum, Nucleonics **11**, No. 8, 48 (1953)

Applying Thermodynamics to Liquid-Metal-Fuel Reactor Technology

By JAMES J. EGAN and RICHARD H. WISWALL, Jr.
Brookhaven National Laboratory
Upton, New York

A knowledge of certain thermodynamic functions, particularly free energies of mixing, has proved useful to the development of the Liquid-Metal-Fuel Reactor. Values of these functions for a number of bismuth alloys have been determined experimentally by a high-temperature galvanic-cell method.

The results obtained help to:

Predict what decontamination factors can be obtained in a fused-salt extraction process.

Assess the utility of metal-metal extraction processes.

Predict whether uranium in the LMFR fuel can react with exposed graphite surfaces and whether fission-product iodine will be removed from the fuel in an outgassing process.

Evaluate the usefulness of an electrolytic process for separating any two elements in the presence of bismuth.

Develop electrochemical methods of analysis and control.

The basic concept and design of a liquid-metal-fuel-reactor system have been described in detail previously (*1*). The fuel is a 0.1% solution of U^{235} or U^{233} in bismuth with small amounts of Zr and Mg added for corrosion inhibition. The reactor is moderated with unclad graphite, and the operating temperature is approximately 500° C.

The fission products formed in the bismuth exhibit a very wide range of physical and chemical properties, but the majority of important ones will be removed by fused-salt extraction and degassing the bismuth in a finely divided state (the latter step removes gases including Xe and Kr).

The most promising molten salt for extraction is the ternary eutectic of $MgCl_2$-KCl-NaCl. This salt will remove the rare-earth metals (one of the major sources of fission poisons) without altering the uranium concentration appreciably.

The activity coefficients of U, Ce, Mg, Na and Li in bismuth have been measured. Their use in describing quantitatively certain equilibria important to the LMFR scheme is set forth here.

Coefficient Measurement

The galvanic-cell method was used to measure all activity coefficients (*2*). The cells were of the form

M (s or l)|M^{+n} + supporting electrolyte|M-Bi (l)

where M is a metal more electropositive than bismuth, M^{+n} is an ion of metal M of valence n, M-Bi is a bismuth alloy of the metal, the supporting electrolyte is an inert molten salt, and (s) and (l) refer to the solid and liquid states, respectively.

The EMF of such a cell is related to the partial molar free energy of mixing and the activity of metal M by

$$\Delta \bar{F}_M = -n\mathfrak{F}E = RT \ln a_M = RT \ln f_M N_M$$

where $\Delta \bar{F}_M$ is the partial molar free energy of mixing; $\mathfrak{F}$, the Faraday constant; E, the electromotive force; T, the absolute temperature; a_M, the activity of the metal; f_M, its activity coefficient, and N_M, its mole fraction.

Since the liquid-metal-fuel reactor operates with very small concentrations of uranium, magnesium and fission products dissolved in bismuth, we shall be concerned here only with very dilute solutions. In this special case $N_M \to 0$ and $f_M \to f_M^\circ$, where f_M° is the activity coefficient at infinite dilution, which according to Henry's law (*2*) does not vary with the concentration.

The cell used in these experiments is shown in Fig. 1. A different cell was used to study the Na-Bi system. The design (Fig. 2) is very similar to that used by Hauffe (*3*) and incorporates a solid electrolyte of soda-lime glass. Figure 3 shows a similar cell used to study several alloy concentrations at once.

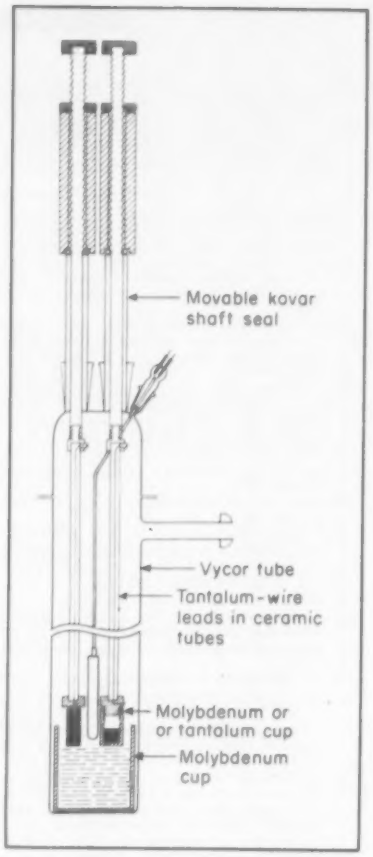


FIG. 1. Galvanic cell used to study activity coefficients in bismuth. Potentials are measured at shaft seal with K-2 potentiometer. Kovar rods are inserted through "true-bore" tubing allowing electrodes to be lowered into molten salt bath in large molybdenum cup. Left-hand electrode is solid pure metal. Measurements are run in argon atmosphere purified over heated calcium chips. Molybdenum and tantalum electrode holders are degassed in high vacuum at 2,000° C by means of induction furnace before cell is assembled. Thermocouple protected with tantalum foil is immersed in salt to measure temperature of experiments

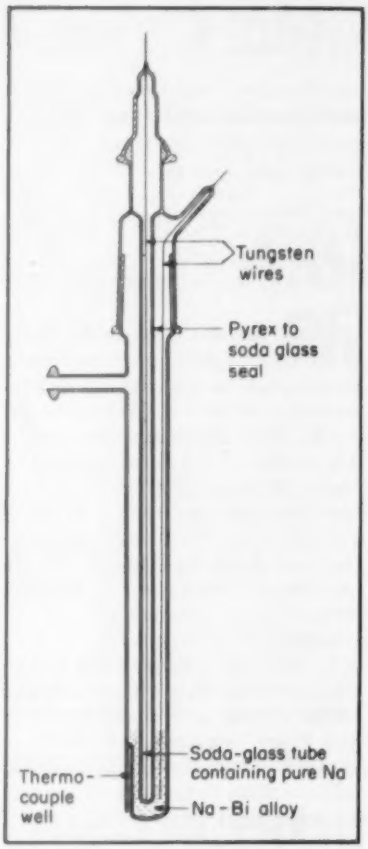


FIG. 2. Galvanic cell used to study Na-Bi system. Electrolyte is solid soda-lime glass

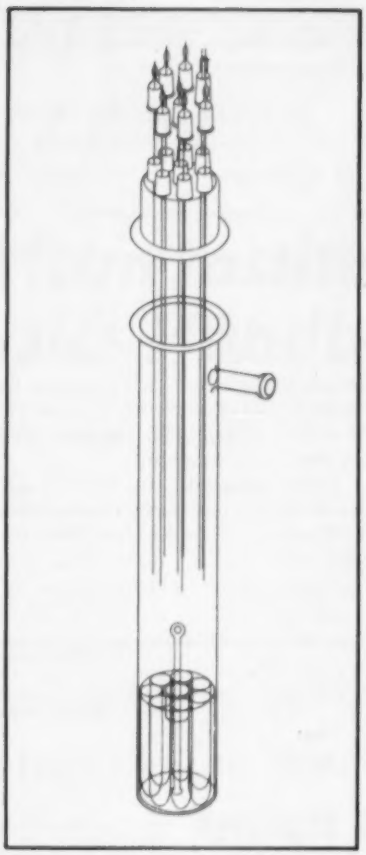


FIG. 3. Cell similar to that of Fig. 2 for studying several alloy concentrations at once

The following cells were studied:

Pb (l)|LiCl-KCl (eut.)
5% $PbCl_2$|Pb-Bi (l)
Ce (s)|LiCl-KCl (eut.)
5% $CeCl_3$|Ce-Bi (l)
Mg (s)|$MgCl_2$-NaCl-KCl (eut.)|
Mg-Bi (l)
U (s)|LiCl-KCl (eut.)
5% UCl_3|U-Bi (l)
Li (l)|LiCl-KCl (eut.)|Li-Bi (l)
Na (l)|soda-lime glass|Na-Bi (l)

The first cell was operated to check cell design since the activity of Pb in Bi was known. Salts used were all anhydrous and purified under vacuum or HCl. Results of these measurements are shown in the table.

Cell Determinations of f_M^0

System	*Temperature (°C)*	f_M^0
Ce-Bi	500	3×10^{-14}
Mg-Bi	500	2×10^{-3}
U-Bi	500	1×10^{-5}
Li-Bi	450	1×10^{-5}
Na-Bi	500	8.5×10^{-5}

Applications

The following examples show how thermodynamic data can be applied to reactor technology and pyrochemical processing of reactor fuels.

Rare-earth extraction. Consider the extraction of Ce (used as a representative rare earth) from a dilute Ce-Mg-Bi alloy by means of the ternary eutectic $MgCl_2$-KCl-NaCl. Since $MgCl_2$ is considerably less stable (*4*) than NaCl and KCl (20–25 kcal/mole), it alone will react with the Ce

$$2Ce(Bi) + 3MgCl_2 \rightleftharpoons 2CeCl_3 + 3Mg(Bi)$$

where the salt and metal phases are assumed to be completely immiscible. The free-energy change of this reaction with all products and reactants in their standard states is related to the equilibrium constant by

$$\Delta F^\circ = -RT \ln K$$

or

$$K = \exp(-\Delta F^\circ/RT)$$

Knowing the free energy of formation of the chlorides (*4*), one calculates

$$K = 7 \times 10^{13}$$

Also

$$K = \frac{a^2_{CeCl_3} a^3_{Mg}}{a^3_{MgCl_2} a^2_{Ce}} = \frac{N^2_{CeCl_3} N^3_{Mg} f^{0\,2}_{CeCl_3} f^{0\,3}_{Mg}}{N^3_{MgCl_2} N^2_{Ce} f^{3}_{MgCl_2} f^{0\,2}_{Ce}} \quad (1)$$

Let

$$\varphi = \frac{f^{0\,2}_{CeCl_3} f^{0\,3}_{Mg}}{f^{3}_{MgCl_2} f^{0\,2}_{Ce}} = \frac{(10^{-1})^2 (2 \times 10^{-2})^3}{(0.3)^3 (3 \times 10^{-14})^3} = 3.3 \times 10^{13} \quad (2)$$

where the activity coefficients in the salt phase are estimated from measurements on similar systems (*5*). We now obtain from Eqs. 1 and 2

$$\frac{N_{CeCl_3}}{N_{Ce}} = \frac{K}{\varphi} \left(\frac{N_{MgCl_2}}{N_{Mg}} \right)^{3/2}$$

Inserting the values of K and φ, we obtain

$$\frac{N_{CeCl_3}}{N_{Ce}} = 4.6 \times 10^{-3} \left(\frac{N_{MgCl_2}}{N_{Mg}} \right)^{3/2}$$

This equation is plotted in Fig. 4 for $N_{MgCl_2} = 0.5$.

The points are taken from laboratory experiments (*6*) where the alloy and salt are contacted in tantalum crucibles and analyses made by tracer techniques. It can be seen that for low magnesium concentrations, Ce will be removed to the salt phase.

Uranium-graphite reaction. Another interesting and important application of these thermodynamic quantities is the study of possible carbide formation by reaction of the dissolved uranium with the graphite moderator. Knowing the activity of U and the free energy of formation of uranium carbide (*7*), one can predict whether a significant amount of carbide will form. The reaction is

$$U\,(Bi) + C\,(s) \rightleftharpoons UC\,(s) \quad (3)$$

$$\Delta F^\circ = -26{,}000 + 2T = -RT \ln K$$

At 500° C, $K = 7.9 \times 10^6$.
Also

$$K = \frac{a_{UC}}{a_U a_C}$$

Assuming that the carbide and the graphite are completely insoluble in bismuth, then at equilibrium they will

ANALOG COMPUTER MODEL 3000

Simplified analog computer solves wide variety of engineering problems. Detachable problem boards and plug-in components facilitate rapid problem set-up.

Can be expanded building block fashion to larger computing system. Function generator, multiplier, chopper stabilizer, and other accessories available. Write for complete data. Model 3000, $1150, FOB Factory.

Problem board $95

DONNER SCIENTIFIC COMPANY

839 Galindo Street
Concord, California

exist in their standard states, i.e., pure solid substance. Therefore, their activities will be unity, or

$$K = \frac{1}{a_U}$$

At equilibrium then

$$a_U = 1.27 \times 10^{-7}$$

but the activity of U at a concentration of 1,000 ppm is only

$$a_U = N_U f^0_U = 8 \times 10^{-8}$$

Since this is lower than the equilibrium value for reaction 3, no carbide will be formed. In other words, the uranium has more affinity for the bismuth than it does for the graphite.

Iodine removal. Another example is afforded by the possibility that iodine will be removed from the reactor in the degassing process. Since iodine is a precursor to the highly poisonous Xe, it would be very advantageous to remove it before it decays.

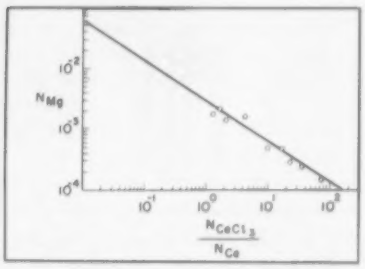


FIG. 4. Extraction of Ce from Ce-Mg-Bi alloy into ternary eutectic $MgCl_2$-KCl-NaCl with $N_{MgCl_2} = 0.5$

Because both U and Bi form stable iodides, the iodine will not exist in the elemental form I_2. If it exists as an iodide of uranium, it will not be volatile; but if it exists as an iodide of bismuth, it should volatilize with dissociation (4). It is also well known that salts dissolve in metals to a limited extent at these temperatures (4), forming compounds whose stoichiometry is considerably different from those experienced at room temperature. In view of these considerations, one might guess that the following equilibrium exists

$$BiI + U\ (Bi) \rightarrow UI + Bi$$

where $\Delta F^0 = -RT \ln K$.

Because the free energies of formation of BiI and UI are not known, they can only be estimated by taking one-third of the values of BiI_3 and UI_3, obtaining $K = 3 \times 10^6$. Again

$$K = \frac{a_{UI} a_{Bi}}{a_{BiI} a_U} = \frac{N_{UI}}{N_{BiI} N_U} \frac{f^0_{UI}}{f^0_{BiI} f^0_U} \quad (4)$$

where $a_{Bi} = 1$ since the solution is nearly pure bismuth. From Eq. 4

$$\frac{N_{UI}}{N_{BiI}} = K a_U \frac{f^0_{BiI}}{f^0_{UI}}$$

If $f^0_{BiI}/f^0_{UI} = 1$, then $N_{UI}/N_{BiI} = 25$.

This amount of BiI should allow the removal of some iodine by a degassing step.

Metal concentrations in Bi. Cells of the type described may also be used directly on a reactor for giving the concentration of various metals in the bismuth. For example, by inserting a Mg electrode into a molten salt bath of $MgCl_2$-KCl-NaCl (eut.) that is in turn in contact with the bismuth solution of the reactor, one will observe a potential that is a direct indication of the Mg concentration in the reactor. The temperature of such a system must be well controlled for accurate results.

In the case of metal-metal extraction, the activity coefficients are also useful. When two liquid metals A and B are immiscible (e.g., Bi-Zn or Bi-Al), and a third metal is distributed between these two metals in contact, the following equation holds

$$N_M{}^A / N_M{}^B = f_M{}^{0B} / f_M{}^{0A}$$

Thus, when the activity coefficients of the metal M are known in metals A and B, the distribution between the two phases may be calculated. The formula holds only when dealing with dilute solutions and is only approximate when metals A and B are not completely immiscible.

Electrolytic processes. In the design of any electrolytic process of fission-product removal, the activity coefficients will be needed to determine the potential to be applied for separating various metals.

* * *

The authors would like to acknowledge the assistance of Raymond Heus, John Bracker and F. L. Bowditch.

BIBLIOGRAPHY

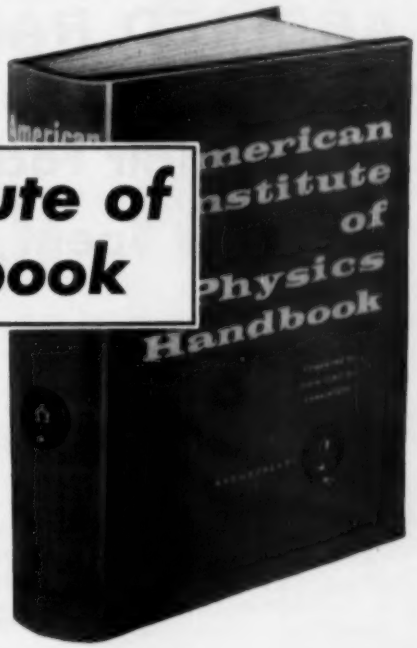
1. NUCLEONICS **12**, No. 7, 11 (1954)
2. C. Wagner, "Thermodynamics of Alloys" (Addison-Wesley Press, Cambridge, Mass., 1952)
3. K. Hauffe, *Z. Elektrochem.* **46**, 348 (1940)
4. L. L. Quill, "Chemistry and Metallurgy of Miscellaneous Materials: Thermodynamics," National Nuclear Energy Series IV-19B (McGraw-Hill Book Co., Inc., New York, 1950)
5. Markov, Delimarskii, Panchenko, *Zhurnal Fizicheskoi Khimii* **29**, 51 (1955); AEC-TR-2212
6. W. Ginell, to be published
7. Brewer, communication to J. Weeks

Newly Published

An all-inclusive reference work, presenting the basic physical data so frequently called upon in scientific, engineering, and research endeavors.

- ★ **One** giant source of information
- ★ Over **90** specialist contributors
- ★ Over **100** subject areas covered in **8** big sections

American Institute of Physics Handbook



Dwight E. GRAY, Coordinating Editor

IN preparing this Handbook, the American Institute of Physics has come up with an all-inclusive reference work. Just like the comprehensive handbooks familiar in other professional areas, it offers you similar fast, reliable, wide-range reference—on *all fields of physics.*

Now you can save yourself hours of searching through scattered reference works for the fact or formula you need to apply physical methods in your work. The book is packed with the tables, graphs, and equations you want on such matters as heat, optics, nuclear physics, etc. Text matter is held to the minimum necessary to make the tabular information understandable and useful.

Each section is the work of a number of specialists in the field who have taken into consideration the many recent discoveries and advances, selecting and compiling for your immediate use the most generally helpful data available today. **Over 1500 pages, $15.00**

Other Books Important to Modern Physicists

NUCLEAR PHYSICS

Here is a systematic, comprehensive study of the properties of atomic nuclei and related phenomena. The book outlines the field in detail, covers the known facts, and shows what areas are still imperfectly understood. The material ranges from a background description of basic phenomena in the field, accelerators, radioactivity, nuclear reactions, and quantum mechanics, to nuclear decay and nuclear forces. **By Alex E. S. Green, Florida State University. 535 pages, 218 illustrations, $9.00**

MESON PHYSICS

This addition to *The International Series in Pure and Applied Physics* is a record of the indisputable facts concerning *pi, mu,* and heavy mesons established since the discovery of the meson in 1947. It is the first attempt to assemble and organize the experimental data from both artificially produced mesons and cosmic ray investigations and integrate this data within the framework of modern meson theory. **By Robert E. Marshak, University of Rochester. 378 pages, illustrated, $8.00.**

LOW TEMPERATURE PHYSICS

Describes the physical properties of matter at temperatures below −**400**°C and shows how these properties obey quantum laws. Experimental methods and results blend with theoretical concepts as the author discusses in detail such experiments on the properties of matter as quantum characteristic properties of gaseous and liquid helium, the behavior of superconductors, and the electromagnetic permeabilities of matter at low temperature. **By Charles F. Squire, The Rice Institute. 244 pages, 146 illustrations, $6.50**

MODERN PHYSICS FOR THE ENGINEER

Nineteen eminent scientists explore with you the basic physical sciences on which our engineering society is built. Written especially for the engineer, the book shows the interesting developments, achievements, and methods used in the various "pure" sciences. Three broadly-defined sections of the book cover the laws of nature, the world we live in, and the communication of information. **Edited by L. N. Ridenour, Lockheed Aircraft Corp. 490 pages, 211 illustrations, $7.50**

SEE ANY BOOK 10 DAYS FREE

McGraw-Hill Book Co. Dept FNU7, 327 W. 41st St. New York 36

Send me book(s) checked below for 10 days' examination on approval. In 10 days I will remit for book(s) I keep, plus few cents for delivery costs, and return unwanted book(s) postpaid. (We pay delivery costs if you remit with this coupon—same return privilege.)

- ☐ **American Institute of Physics Handbook,** $15.00
- ☐ Green—**Nuclear Physics,** $9.00
- ☐ Marshak—**Meson Physics,** $8.00
- ☐ Squire—**Low Temperature Physics,** $6.50
- ☐ Ridenour—**Modern Physics,** $7.50

Name.....

Address.....

City and Zone..... State.....

Position..... Company.....

For price and terms outside U.S., write McGraw-Hill Int'l. N.Y.C. FNU-7

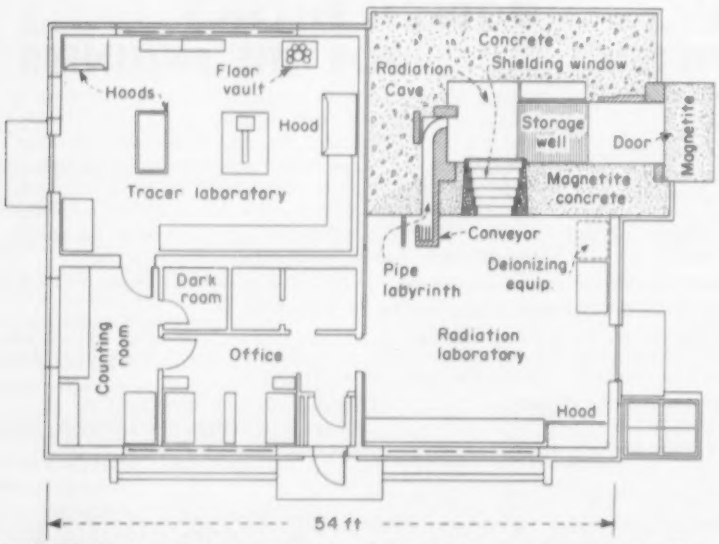
Sinclair Facility Uses Spent MTR Fuel

Spent fuel elements from the Materials Testing Reactor at Arco, Idaho, supply the radiation in an unusual gamma facility recently opened at the Sinclair Research Laboratories, Harvey, Ill., near Chicago. Four elements that have been aged ~300 days are now in use for initial experience, but shielding and handling facilities are sufficient for up to eight elements aged as little as 20 days after their reactor service. This is the first industrial irradiation facility licensed by the Atomic Energy Commission for the use of spent fuel elements.

The drawing shows the plan of the new radiation-laboratory building. The radiation cave includes an 18-ft-deep water-filled well for storage of the elements. Access is through a 155,000-lb magnetite-ore-filled door interlocked with the source-handling mechanism so that the door can be open only when the source is locked down in its storage position. Shielding of the cave is thick enough that no change in background can be observed in the nearby counting room with either G-M or scintillation counters as the source is raised from the storage well. Since the present elements have $\frac{1}{10}$ the radiation strength of those expected in the future, it is anticipated that background differences may be observable with more active elements.

Process irradiations. In the photograph can be seen the top of a special process vessel surrounded by the four spent fuel elements. Vessel and source holder are designed so that an experiment can be set up in the cave and then carried out remotely from the adjacent radiation laboratory. The vessel can be connected to experimental equipment in the laboratory by means of pipes, tubes, and wires that pass through the pipe labyrinth. After the experiment is arranged, the radiation source can be raised from its well and positioned around the process vessel. This motion is accomplished by turning the hand wheels shown in the photograph. Meanwhile manipulations in the radiation area can be accomplished with the manipulators shown. The conveyor is designed to carry things to and from the radiation area while experiments are in progress.

RADIATION CAVE. Handwheels below viewing window raise spent fuel elements from storage pool, and place them around special process vessel designed for facility



FLOOR PLAN shows counting room at lower left, radiation cave at upper right. Pipe labyrinth connects cave and adjacent laboratory so that irradiations and measurements can be made simultaneously

Dose from the elements now in use is 216,000 r/hr at the center of the configuration when the elements are in water. These will soon be replaced by 90-day-cooled elements that will deliver 800,000 r/hr. Eventually it is planned to use 30-day-cooled elements, and these will deliver 2.5×10^6 r/hr. Thus the eventual source will be equivalent to ~46,000 curies of Co^{60} used in the same geometry.

Advantages of spent fuel. Spent fuel was chosen as the radiation source for several reasons. (a) It will deliver more gamma energy than currently available Co^{60} sources. (b) The MTR elements have large physical dimensions, which make them convenient for use with standard process equipment. (c) Their radiation represents fairly well the spectrum that will be available from reactors designed especially for radiation processing. (d) Gamma radiation is suitable for use with heavy process vessels that are required for high-pressure experiments.

the

Van de Graaff®

your radiation source for

REACTOR RESEARCH

- **Enables you to initiate or to supplement a reactor development program without large capital cost.**
- **Chosen by physicists and engineers throughout the world for its versatility.**

Producing separately all the radiations encountered in a reactor, the Van de Graaff is safe and stable in operation for work on:

Radiation effects — Synthesis of effects occurring in nuclear reactors, under accurately controllable circumstances.

Neutron sources — Precise cross-section data with monoenergetic neutrons.

Reactor kinetics — Pulsed neutrons for investigations of critical and sub-critical assemblies — neutron multiplication — observation of delayed neutron spectrum.

Activation analysis — Simplification of reactor activation techniques — rapid quantitative trace determination.

Nuclear physics — Fundamental data regarding nuclear structure and particle interactions.

X-ray inspection — Precision radiography to meet rigid requirements of reactor industry. High-density-alloy inspection.

For details, ask for new Bulletin H.

HIGH VOLTAGE ENGINEERING
CORPORATION
BURLINGTON MASSACHUSETTS

Industrial Nuclear Technology Conference Shows . . .

. . . Worldwide interest in applied uses of radiation. Here, Japanese delegates compare notes on conference as . . .

. . . Belgians (two facing camera on left) enjoy corridor smoke while others registered at conference which showed . . .

. . . Radiation Use Expanding

Satellite wear, neutron irradiation of glasses, polymer dosimetry are among subjects at conference on nonpower nuclear technology

A RADIOACTIVE surface and a 1-oz detector will determine the wear rate of the first earth satellite. Textiles may someday be dyed by means of irradiation. These were among novel uses of isotopes and radiation described May 14–16 in Chicago at the second Industrial Technology Conference. Some 40 speakers discussed latest advances in the use of radiation effects, improved nuclear techniques, and advances in nuclear instrumentation.

Tracer Experiments

Most novel among the uses of tracer isotopes reported is the determination of the wearing away of the surface of a satellite or space ship. **S. F. Singer** (University of Maryland) described a system designed for the first earth satellite of Project Vanguard. A radioactive coating on the surface of the satellite will wear as the satellite encounters interplanetary dust. A measure of the rate of wear will give information on the endurance of the surface and also on the nature of the dust it encounters. A detector weighing less than 1 oz is mounted near the skin of the satellite to detect the radiations and transmit its information to the parent planet.

G. G. Eichholz (Canadian Department of Mines and Technical Surveys) spoke on the use of tracers in large ore-processing plants. Irradiated ore samples and salts that adsorb on ore particles are used to follow particles, determine contact times, and measure circulation times, recirculation, and short-circuiting.

Radiation Effects

Several papers were devoted to radiation effects in polymer systems. An interesting application is a high-dose go–no-go dosimeter that is likely to have application in food-irradiation problems and radiation processing. **F. E. Hoecker** and **I. W. Watkins** (University of Kansas) fill gelatine capsules with a mixture of styrene polyesters that gel upon exposure to radiation. A small steel ball in the capsule indicates gelation, since it will no longer fall through the material after gelling has taken place. The threshold dose can be adjusted between 30,000 and 250,000 r by adding an inhibitor, which is a scavenger for the radicals that lead to gelation. The inventors believe that the threshold can be extended to higher doses without limit.

The future will see neutron irradiation used to change refractive indices of glasses, according to **N. J. Kreidl** and **J. R. Hensler** (Bausch and Lomb Optical Co.). Neutrons will also be a research tool to study glass structures, they said. In an invited paper on radiation effects in glass these authors discussed current uses of glass in dosimetry, shielding, and radiation-resistant optics. They pointed out that both darkening and fluorescence are being used as dose indicators. Dosimetry glasses now reach 10^7 r.

D. I. Gordon and **R. S. Sery** (Naval Ordnance Laboratory) described the effects of reactor radiation on magnetic materials. They studied the magnetic response of seven commonly used magnetic materials during and after irradiation in the Brookhaven reactor: 2 V Permendur, 16 Alfenol, and 3.5% silicon-iron showed the smallest changes during irradiation and almost complete recovery afterward. Some materials showed changes only in their response to frequencies in and slightly above the audio range, and others showed significant changes in mechanical properties that would affect their functioning in magnetic devices.

Disagreement with current theories of radiation effects in high polymers was expressed by **M. Dole** and **D. C. Milner** (Northwestern University). They assert that the two most significant effects are hydrogen-gas liberation and production of unsaturated bonds. This is evidenced by their experiments in irradiating polymers at low temperatures.

A possible new application of ionizing radiation was suggested by **J. Saldick** (Advanced Scientific Techniques Research Associates), who is studying the dyeing of synthetic fibers with their aid.

W. J. Kosiba and **G. J. Dienes** (Brookhaven National Laboratory) described experiments on effects of reactor radiations on graphite. Oxidation is increased by previous irradiation, and it is further increased if the oxidation takes place in the presence of gamma radiation.

Nuclear Techniques

Newly designed accelerators were described by speakers from Canada and Japan. **P. Lorrain** (Univerite de Montreal) described a pressurized high-frequency Cockcroft-Walton accelerator. The instrument has 24 stages and operates at 32 kc. It is capable of a 500,000-volt output, stable to $\pm 1\%$, and it will supply a 125-μa beam of deuterons. Paradoxically, the 24-stage design leads to compactness.

H. Kamogawa and his associates (Tokyo Shibaura Electric Co.) have developed a light-weight betatron. In describing it they pointed out that its weight is only 1,035 lb as compared to the 3–8 tons of the usual betatron. The 15-Mev instrument is intended for medical therapy and industrial radiography.

A new use of neutron beams is in measuring the glass content of glass-reinforced plastic laminates. The system depends mainly on absorption of thermal neutrons by the boron of the glass. A difficulty arises from scattering by the plastic. To make the system insensitive to the amount of plastic present a moderation-diffusion method has been developed using a source of epithermal neutrons. **D. G. Simons** (Naval Ordnance Laboratory) described it. A hydrogenous moderator in front of the sample slows fast neutrons to thermal. A diffuser between sample and detector scatters thermals out of the beam. By adjusting the thicknesses of the two it is possible to achieve such a balance that additional plastic subtracts as many thermals by scattering as it adds by moderation.

The polonium-beryllium reaction is now used in the detection of hazardous air-borne beryllium dust. Samples collected on filter paper are exposed to Po^{210} alphas. Counting of the resulting gamma rays indicates the beryllium concentration. **R. Gold** (Armour Research Foundation) described the system.

H. L. Cook (Ohmart Corp.) spoke on a liquid-level gage with a range of 45 ft and $\frac{1}{8}$-in. accuracy. The system uses a point source, a point detector, and a servo system that causes both source and detector to follow the liquid.

Instrumentation

Two papers by researchers at Armour Research Foundation discussed the use of proportional counters with X-rays. **K. Rothschild** described fluorescence spectroscopy capable of detecting as little as 10^{-5} gm of a substance. **D. Greenberg** and **L. Reiffel** discussed absorption measurements designed for organic analysis. The method consists of measuring the absorption of monochromatic X-rays at several frequencies and solving the resulting simultaneous equations.

Two papers presented improvements in beta-ray spectroscopy. **D. B Beard** (Lockheed Missile Systems Division) has improved the performance of uniform-field helical-orbit spectrometers by designing collimating slits to restrict the direction of injected particles. **W. W. Meinke** and **D. G. Gardner** (University of Michigan) have designed and used hollow scintillators to minimize electron escape. They have been able to study beta spectra down to energies of 0.1 Mev.

Why & Who of Conference

The Industrial Nuclear Technology Conference, in its second year, cosponsored again by NUCLEONICS and the Armour Research Foundation, was set up to serve as a specialized forum on the nonpower aspects of nuclear technology. Drawing its attendance from users and designers of radiation sources and equipment, the meeting attracted 300 registrants from 236 laboratories and 12 foreign countries. Again, in a survey conducted at the conference, attendees were almost unanimous in requesting continuation of it on an annual basis. This is expected. In fact, ideas for papers for 1958 should be submitted to ARF or NUCLEONICS.

CONFERENCE BANQUET is addressed by Norman Hillberry, director of Argonne National Laboratory speaking on "The Challenge of Industrial Nuclear Technology"

BOOKS

Atomkraft

By FRIEDRICH MUNZINGER (Springer-Verlag, Berlin, 1957, xi + 224 pages, $7.00).

Reviewed by DAVID EPSTEIN, Defense Electronic Products, Radio Corporation of America, New York, N. Y.

This is the second edition of a book that apparently has been very well received, for in a matter of only a few months the first edition was completely sold out. This is undoubtedly due not only to the subject, but also to the author's lucid style.

The book is divided into three parts. In the first part, Dr. Munzinger treats the theoretical preliminaries. Among the topics covered are atomic structure, splitting of the nucleus, nuclear transformation, chain reactions, slow and fast neutrons, biological and thermal shielding, the methods of measuring used in atomic physics and the cooling of reactors.

The second part deals directly with nuclear reactors and includes a survey of gas-cooled heterogeneous reactors, water-cooled reactors, fast-breeder reactors and liquid-metal-cooled reactors. Consideration is given to the utilization of the heat generated in a reactor and in particular to the conversion of this heat into electrical current. Also considered here is the danger of reactor accidents.

In the third part the author considers some of the economic questions that have motivated the international race in atomic power facilities; conventional fuel prices vs "atomic" fuel costs; depletion of conventional fuel resources; the necessary scientific talent; the progress of England, America, Russia and Germany in the building of atomic power plants.

It is regrettable that this fine book will be, in effect, unavailable to the large number of workers in this field who cannot read German.

BOOKS RECEIVED

Semiconductor Abstracts, Vol. 3, 1955, edited by E. Paskell (John Wiley and Sons, Inc., New York, 1957, vii + 322 pages, $10.00). The coverage of these abstracts, compiled by Battelle Memorial Institute, is expanded to include conference papers. Results are included in most abstracts.

Magnetic-Amplifier Circuits, 2nd. ed., by William A. Geyger (McGraw-Hill Book Co., Inc., New York, 1957, xiii + 394 pages, $7.00). Descriptive and graphical methods are primarily used for qualitative and quantitative explanations. Revised material includes that on single-ended and push-pull self-balancing amplifiers, static and dynamic performance with or without positive feedback, instrumentation circuits and new applications.

Light Scattering by Small Particles, by H. C. van de Hulst (John Wiley and Sons, Inc., New York, 1957, xiii + 470 pages, $12.00). This book is divided into three sections: basic scattering theory, the physics of special particles and applications.

Nuclear Weapons and Foreign Policy, by Henry A. Kissinger (Harper and Brothers, New York, 1957, xx + 455 pages, $5.00). Although an expression of Kissinger's opinions, this book was stimulated by discussions of a group chaired by Gordon Dean and sponsored by the Council on Foreign Relations. Kissinger compares Russian and U. S. foreign policy operation, delineates the complexities introduced by nuclear weapons, and points out the need for a clearly stated doctrine to define the future course of U. S. policy.

La Chimie Nucleaire et Ses Applications, by M. Haissinsky (Masson & Cie., Paris, 1957, 651 pages, about $16.00). Four main fields of nuclear chemistry are covered in this book: nuclear properties and transformations, the radioelements and the physical-chemical behavior of the imponderable quantities of matter, radiations and their effects and radioactive and isotopic tracers.

Pump Selection and Application, by Tyler G. Hicks (McGraw-Hill Book Co., Inc., New York, 1957, xiv + 422 pages, $8.50). This book is written as a guide to select the best pump for a given set of conditions, from the smallest pump to the largest. A chapter is devoted to nuclear engineering applications. This chapter, in 11 pages, describes the types developed to meet the zero-leakage requirement for radioactive fluids. Among the other chapters are those on power plants and chemical industries.

Grundlagen und Arbeitsmethoden der Kernphysik, edited by Gustav Hertz (Akademie-Verlag, Berlin, 1957, 279 pages, about $4.17). This introductory text contains 8 chapters: the basis of nuclear physics (Hertz), nuclear structure (Macke), nuclear reactions (Richter), nuclear physical measuring methods (Weiss) and tools (Hartmann), nuclear reactors (Barwich), radiochemistry (Born) and paramagnetic nuclear resonance (Losche).

Radioactivity and Nuclear Physics, 3rd ed., by James M. Cork (D. Van Nostrand Co., Inc., Princeton, 1957, xii + 415 pages, $7.75). This introductory book contains a new chapter on recent nuclear-model theory and new material on accelerators and newly discovered particles.

Elementary Theory of Angular Momentum, by M. E. Rose (John Wiley & Sons, Inc., New York, 1957, x + 248 pages, $10.00). This book is the result of a course given at Oak Ridge. It is written for the widest possible audience out of those with a graduate-course knowledge of quantum mechanics.

Transistor Circuit Engineering, edited by Richard F. Shea (John Wiley & Sons, Inc., New York, 1957, xx + 468 pages, $12.00). Although this book is mainly concerned with transmitting and receiving circuitry, instrument designers will find the introductory chapters, a 60-page chapter on gating and pulsing circuits and another on special circuits of interest.

Kurven und Tabellen fur die Strahlentherapie (S. Hirzel-Verlag, Stuttgart, Germany, 1957, 184 pages, $6.67). This little book presents graphs and tables to guide the radiotherapist in determining proper dosage.

The latest measurements and, in general, the measurements that are regarded as the most reliable, are included.

There are five chapters treating the following subjects: general Matters (tables of the elements, etc.), dosimetry, determination of surface and depth dose, radium and radioactive isotopes and biology.

This book will be available to a large number of workers in the field, since each page of German is repeated in English, French and Spanish.

ALSO OF NOTE

The Isotope Index. In the revised 1957 edition of this guide, all commercially available stable and radio-

active isotopes, as well as 697 labeled compounds, are listed from 53 U. S., Canadian, British, French and German suppliers. Information includes half-life, specific activity and price. 100 p. *Scientific Equipment Corp., 23 N. Hawthorne Lane, Indianapolis 19, Ind., $3.00, foreign $3.50.*

Stable Isotopes and **Radioisotopes.** These 1957 editions of the catalogs and price lists list all enriched stable isotopes and radioisotopes available from the Isotopes Division, Oak Ridge National Laboratory. The radioisotope catalog describes reactor and cyclotron irradiation facilities available. *Isotopes Sales Dept., Union Carbide Nuclear Co., Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tenn.*

Multichannel Pulse Height Analyzers (Publication 467). This publication, edited by H. W. Koch and R. W. Johnston, presents the proceedings of a conference sponsored by the NAS-NRC, Sept. 26–28, 1956. Coverage includes analyzer systems, computer techniques, and future needs and applications. 202 p. *National Academy of Sciences–National Research Council, 2101 Constitution Ave., Washington, D. C., $2.00.*

Annals of Physics. The editor of this new monthly journal is P. M. Morse; assistant editors are B. Feld, H. Feshbach and R. Wilson. *Academic Press Inc., 111 Fifth Ave., New York 3, N. Y.; vol. 1 (April–June '57), $8.00; vol. 2 (July–Dec. '57), $14.00.*

Microprints of Declassified Papers. Microprints of papers abstracted in *Abstracts of Declassified Documents* and *Nuclear Science Abstracts* since July '47 will be available as microprints (100 book pages on one side of 6 × 9-in. card). Cards are projected on an illuminated screen. *Readex Microprint Corp., 115 University Place, New York, N. Y.*

Fractional Factorial Experiment Designs for Factors at Two Levels. This monograph in the National Bureau of Standards Applied Mathematics Series 48 contains designs for the case when all factors are at two different conditions. Fractional experiment plans are cataloged for experiments having 5 through 16 factors. 85 p. *Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., $0.50.*

For Assistance in Radiation Protection

If you are designing structures or devices to house, handle, or transport radioactive materials, Federated can help you.

With long years of experience in research, development, and the production of lead for radiation protection, and in the design of structures using lead for this purpose, Federated's experienced metallurgists can supply you with authoritative information, help you develop practical lead protection devices. Working with nuclear scientists, Federated has designed interlocking lead bricks for use in the construction of nuclear power reactors, lead containers for storing and shipping radioactive isotopes, other containers for transporting and disposing of atomic wastes.

Lead is the most efficient protection against gamma rays because it is the densest of readily available low-cost materials and because it is not contaminated from exposure to radioactive materials.

Federated will be glad to work with you on any problems of incorporating lead into structures or devices that must provide radiation protection. Just call your nearest Federated office.

Federated Metals ASARCO

Division of

AMERICAN SMELTING AND REFINING COMPANY

120 Broadway • New York 5, N.Y.

In Canada: Federated Metals Canada, Ltd., Toronto and Montreal

TULLAMORE announces the Model VTE-1

VACUUM TUBE ELECTROMETER

The VTE—1 is a practical instrument for the modern nuclear physics laboratory. Small currents may be measured accurately and reliably. A bucking current supply enables the operator to measure extremely small current variations.

—RELIABLE—
—INEXPENSIVE—
—PRECISE—

SPECIFICATIONS:

1. Current Range—10^{-3} to 10^{-11} amps.
2. Bucking Current Range—10^{-3} to 10^{-9} amps.
3. Time Constants—0.1, 0.3, 1, 3, 10, and 30 seconds.
4. Drift—less than $\frac{1}{2}$% per day after $\frac{1}{2}$ hour warmup.
5. Trip Circuits—Hi and Lo level trip circuits may be included for reactor control applications.

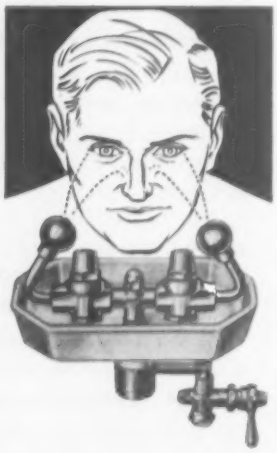
IDEALLY SUITED FOR THE MEASUREMENT OF CURRENTS FROM SCINTILLATION COUNTERS AND IONIZATION CHAMBERS

Address inquiries to:

TULLAMORE
ELECTRONIC LABORATORY
6055 South Ashland Ave. • Chicago 36, Illinois

the **SAFE** INVESTMENT

HAWS EYE-WASH FOUNTAINS



FIRST AID equipment for eyes is one of the best investments you can make! It minimizes costly insurance claims and thereby lowers your workman's compensation insurance rates—by reducing lost-time eye injuries.

Employees can cleanse injurious chemicals and particles from their eyes *instantaneously*—before the necessary medical aid can be reached. *HAWS Eye-Wash Fountains* and emergency drench showers are designed and manufactured in cooperation with leading Safety Engineers—they provide clear water at controlled pressure.

At a minimum investment, this valuable safety equipment practically pays for itself in reduced insurance rates. Write for full details TODAY!

HAWS DRINKING FAUCET CO.
1437 FOURTH STREET (Since 1909) BERKELEY 10, CALIFORNIA

LETTERS

Uranium in Rocks

DEAR SIR:

I have read with interest the article on "Autoradiographic Determination of Radioactivity in Rocks," by A. P. Abrahams (NU, March '57, p. 85). This is yet another of a long line of articles that have been published from time to time on the use of autoradiographic methods for the assay of uranium in rocks, and it contains several assertions that I consider misleading and worth rebutting.

While there can be no question of the usefulness of autoradiography in mineralogical investigations, its sensitivity is too low to give sufficiently precise assays in a reasonable time. The author claims that his method is more precise, more adapted to use in the field and less expensive than a counter. In actual fact it is hard to conceive anything less portable than a fully equipped darkroom with a densitometer, bearing in mind that the samples must be exposed undisturbed for 2-3 weeks. The cost of a densitometer of the required accuracy would be comparable with that of a good-quality ratemeter or simple scaler. The amount of shielding required for a counter is not very great and there is no need for an automatic sample changer as suggested, as it would take longer for one man to crush and grind the samples to the required size and to fill the sample containers than is needed to obtain an adequate count.

If the samples shown in Fig. 2 are representative, then the nonuniformity of the samples themselves would rule out completely the possibility that the densitometer reading would give anything more than an approximate indication of the uranium grade. Even with more careful grinding and mixing, however, the inherent limitations of the photographic response curve introduce far greater errors than the counting statistics of a radiation counter. Presumably a new calibration curve has to be plotted for every film to allow for variations in development.

It would have been useful if results had been included to compare radiometric and radiographic assay results for the same samples.

It is hoped that these remarks will help to clarify some of the points arising from such a typical extrapolation of

laboratory investigations to uranium field assaying. Detailed descriptions of assay methods for radioactive ores suitable for field conditions have been published by this Department and by the U. S. Geological Survey.

—G. G. Eichholz
Radioactivity Division
Department of Mines and Technical Surveys
Ottawa, Ontario
Canada

Dear Sir:

I have read Mr. Eichholz' letter with a great deal of interest. Several of his points are well taken, but based on a mental picture of the situation that is different from mine.

The fully equipped darkroom and densitometer need not be portable. The cassettes may be sent back from the field to the place where this equipment is located for processing. The exposure time required for low-grade samples is, of course, a disadvantage.

An accurate densitometer is on the market for $500. Descriptive catalogs of suitable shielded scalers and counters quote prices of $1,000 or more, even without automatic sample changers.

I disagree with Mr. Eichholz about the amount of shielding required for a counter, where the sample counting rate is barely above background.

Crushing and grinding time may be appreciable where the work has to be done manually. However, I have found that for accurate sampling and reproducible geometry, the rock samples should be crushed and ground before counting as well. Grinding to a fine, uniform consistency is important, and Mr. Eichholz is right in saying the samples depicted did not measure up to the usual standards.

A new calibration curve does, in theory, have to be plotted for each sample, but in practice the only work involved is a linear interpolation between two given standard values.

Although no comparative values for radiometric and radiographic determinations were included in the article as published, the precision of the measurements by radiographic means was greater than by radiometric means for low-activity samples. The opposite held true for high-activity samples.

I wish to thank Mr. Eichholz for his constructive and instructive criticism.

—Albert P. Abrahams
Division of Industrial Hygiene
New York State Department of Labor
New York, N. Y.

U. S. RADIUM
RADIATION AND LIGHT SOURCES
TAILORED TO YOUR SPECIFICATIONS

Beta gauge sources for thin stock; many configurations, intensities, energies. Low energy sources incorporate Mylar or mica windows, contain Kr^{85}, Tl^{204}, H^3, C^{14}, Ni^{63}, Pm^{147}, Sr^{90}.

Extended gamma sources utilizing active foil for extreme uniformity of emission along source axis; for liquid level and interface gauges, incorporates either Ra, Co^{60}, Cs^{134}, Cs^{137}, Eu^{153}.

Custom light sources and source holders for process control instrumentation. Sources feature selective spectral emission, long stable life, utilizing either solid or gaseous beta emitters. Minimal extraneous radiation.

Gamma source, general 2π emission design for gauging, radiography, irradiation.

Intensity: from uc. range to 300 millicuries. Co^{60}, Cs^{134}, Ra, Eu^{153}.

High brightness obstruction markers, backlighted exit signs, and maintenance-free signal lamps all utilizing long-lived nontoxic beta-emitters. Reflector prototype (illustrated) designed to your spec. Brightness to 1000 μl. Visibility to 500 yds.

Neutron sources for reactor startup, activation and H-content analysis, borehole logging. Total emission from $2.5(10^3)$ — 2.5 (10^7) n/sec. Provision for magnetic handling; calibration ($\pm$15% to NBS standard) optional.

Beta source, general manual-handling design, minimal extraneous radiation. Excellent thin-window design for low-energy betas: Ni^{63}, H^3, C^{14}, Pr^{147}.

Stable, sealed light sources for photometric reference, instrumentation, process control. Selective spectrum, brightness from <1—1000 μl. Calibration optional. Shielded. Utilizing H^3, Kr^{85}, C^{14}, Sr^{90}.

Thin-walled gas-filled gauge sources provide highly uniform beta emission over entire length — for scanning wide stock. Broad range of intensities, utilizing non-toxic H^3, Kr^{85}.

U. S. Radium will consult on design of sources to meet your specifications. Write Department F-7

UNITED STATES RADIUM CORPORATION
Morristown, New Jersey

USR RADIUM

5942 W. Chicago Ave., Chicago 51, Illinois
5420 Vineland Ave., North Hollywood, California

Affiliates
CANADA: Radelin-Kirk Ltd., 1168 Bay St., Toronto, Ont.
EUROPE: United States Radium Corporation (Europe)
36 Avenue Krieg, Geneva, Switzerland.

PRODUCTS AND MATERIALS

Polyethylene Tubing for Instrumentation Application

By BRANDT KUPERSTOCK
Instrument Department
Oak Ridge National Laboratory
Oak Ridge, Tennessee

In today's ever-changing world, new product follows new product at a dizzy pace, and the man is lucky who can keep up. There is always something new to experiment with. Take polyethylene tubing, for instance. Here is a real departure from what we are used to. How best to use it? What will it stand up to? What does it cost? Why isn't it used more?

Advantages

All of us are familiar with copper tubing. It is soft, but when you bend it, it gets hard. It hardens when it is pulled and straightened. When it is bent with a bender, and lined up in racks, it has a precise look to it. Briefly, it looks real neat. Polyethylene isn't like that at all. A while back, I was talking to a tubing and fitting salesman. He was explaining some of the techniques they have worked out for handling polyethylene, and showing some pictures of panel-rear installations. He said: "Plastic tubing doesn't make a neat installation, like copper, but no matter what changes you make, or how often you replace instruments, it never looks worse!" Some recent experiences with the stuff bear him out.

Take the case of a panel and cubicle installed in a corrosive area. For protection from the atmosphere, a number of transmitters were installed behind the panel on a floor-to-ceiling rack. Using color-coded tubing, construction pipefitters quickly tubed up sixty-three tubing runs between field, panel, transmitters, and air supply. Sort of sloppy, compared to the metal tubing neatly installed in racks we were used to—but colorful. As all tubing had been fully detailed on the prints, imagine our dismay when we discovered that all the transmitter supplies and outputs had been reversed! It was fortunate that the pipefitters had left plenty of slack in the tubing bundles. We merely had the tubes removed and exchanged—took about ten minutes!

Before our first installation, we tried some burn tests with short lengths of tubing. Held in a match, it melts a little and burns slowly. What was interesting to us was the result of a test under a burning torch. A welder was cutting some angle iron, and we held a piece of plastic tubing under the shower of sparks. Even after some drops of molten metal had fallen on the tubing, and rolled off the side, there were no marks visible on our sample.

After seeing that, we decided to run some temporary hook-ups through an open area, even though we knew there would be welding and burning going on there later. The tubes were bundled with plastic tape and held in place with pipe clamps. After the welders had done their worst, we got a call from the operators—instruments weren't working. Investigation showed the system was suffering from leaks—lots of them. Searching along the tubing bundle, we found a place six inches long where welding sparks had fallen on the tubes. Drops of metal had been trapped in the crevices between the bundled tubes. Unable to roll off, they had burned little holes in several tubes. Although this was an unlucky accident, it was well that it happened before we had decided on other jobs. We take the precaution now of putting open runs of plastic tubing inside conduits.

These holes also showed us an advantage of plastic tubing. Short lengths including holes were clipped out and replaced with compression unions. Tools—one penknife, two wrenches!

Polyethylene's Properties

Polyethylene is a polymer. Its molecules are composed of large numbers of ethylene radicals bonded together in chains. The longer these chains are, the higher the melting point and greater the strength. To insure these valuable properties, an average molecular weight of 15,000 should be specified. This assures you a melting point of higher than 200° F, and a bursting strength of 250 psig, or more, at 100° F. Polyethylene can be extruded to exacting dimensions, so that ¼ in. tubing can be specified as 0.250 in. O. D. ±0.005 in. Standard wall thickness is 0.040 in. Also, it's readily available in lengths of 1500 ft, or even longer. The plastic readily takes Bakelite dyes, and can be had in black, brown, red, yellow, orange, green, blue, violet, and natural.

The tubing can be cut off to a sharp, square end with a penknife. A single ¼-in. tube can be bent to a 1-in. radius, though it must be clamped to hold this bend. Tubes can be bundled, and taped with plastic scotch tape, but must be supported to prevent sagging.

One of the nicest things about polyethylene tubing is the cost—3.3¢/ft. Installation costs are also considerably less than for metal tubing.

* * *

Based on an article in the Oak Ridge Recorder published by the Oak Ridge Section, Instrument Society of America.

Similar user reports of product experience would be welcomed by NUCLEONICS.

Packless Valves for HRT

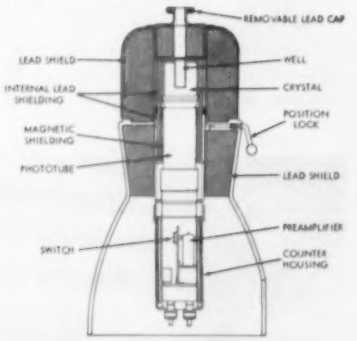
Packless stainless steel valves about the size of a man's fist are used in the primary control system of Homogeneous Test Reactor at Oak Ridge National Laboratory.

Low-pressure valves were designed for 500 psig at 250° C with bodies and assemblies hydrostatically tested at 100 psig, room temperature. Actual operation conditions are 250 psig at 100° C. Poppet materials are stellited stainless steel and characterized with 58 deg taper. High-pressure valves were designed for 2500 psig at 300° C with bodies and bellows hydrostatically tested at 3750 psig, room temperature. Actual operation conditions are 200 psig at 300° C. Most valves are furnished with bellows actuator and few with slip stems and hand wheels. Valve sizes are ½ in. with Autoclave or welding connections. Bellow actuators are reversible, spring-loaded and all-metal. Working area is 40 in.² with maximum working pressure of 75 psi, giving an approximate 3000 lb thrust for $1\frac{3}{16}$ in. maximum thrust.—Robertshaw-Fulton Controls Co., Knoxville, Tenn.

RADIATION DETECTORS AND ACCESSORIES

Roentgen Meter

Model RP-1 has small anthracene crystal mounted in slender probe to insert into body cavity for obtaining γ and X-ray dose rates.—NRD Instrument Co., 6425 Etzel Ave., St. Louis 14, Mo.

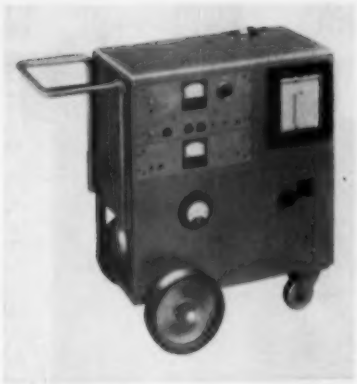


Scintillation Well Counter

Unit includes: scaler spectrometer, 2 in. lead shielding surrounding NaI well crystal and detector that can be removed from lead shielding to permit substitution of other crystals. Over-all sensitivity is ~50%; background counting rate when used with scaler or ratemeter is ~300 cpm and is reduced to 20–30 cpm when used with gamma-ray spectrometer.—Nuclear-Chicago Corp., 223 W. Erie St., Chicago 10, Ill.

Products Index

Radiation Detectors and Accessories 117
Radioactivity Materials and Apparatus 117
New Materials 119
Literature Available 120
Industry Notes 121



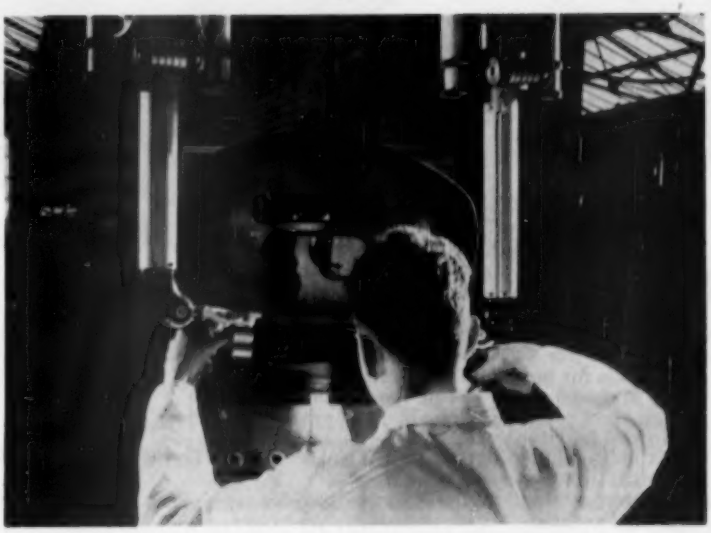
Mobile Monitor

Radiation level of dust contamination can be detected with mobile air particle monitor. Has log count that gives range of 5 decades from 10–1 μcpm on single scale.—Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

Photomultiplier supply. Model CS-324XA supplies 800–2000 volts at 0–5ma, regulated to $\pm 0.005\%$, against $\pm 10\%$ line charges with 0.035 volt regulation.—NJE Corp., 345 Carnegie Ave., Kenilworth, N. J.

Carbon counter. Model TGC–14 incorporates high-sensitivity, small-volume, thin-window flow counter for low-energy β emitters.—Tracerlab, Inc., 1601 Trapelo Rd., Waltham, Mass.

RADIOACTIVITY MATERIALS AND APPARATUS



New Team: Stereoscopic Television and Master–Slave

At Britain's nuclear center in Harwell, stereoscopic television cameras assist in handling radioactive materials. TV equipment consists of two industrial Vidicon cameras, two control units, and two display monitors used in conjunction with master–slave manipulator thus permitting remote handling at distances up to half a mile.

Cameras are mounted side-by-side, with their sight lines inclined so they intercept at point-of-interest. Left-hand camera corresponds to left eye and connects to one monitor thus giving a left-eye view of the scene. Right-hand camera works similarly. Two monitors are positioned in display cabinet so pictures are superimposed by means of half-silvered mirror. Vertically polarized filter covers one screen face while the other is covered by second polaroid filter which is horizontally polarized. If composite image is seen through polarized spectacles, stereoscopic effect is obtained.

With camera, object within hot cell retains its dimensions, avoiding distortions sometimes experienced viewing through glass shield. Also, close-up view of experiments are possible. TV equipment costs $7,500 while manipulator is priced at $3,360 a hand.—(television) Marconi's Wireless Telegraph, Ltd., Chelmsford, Essex, England; (manipulator) Savage & Parsons, Ltd., Watford, Hertfordshire, England.

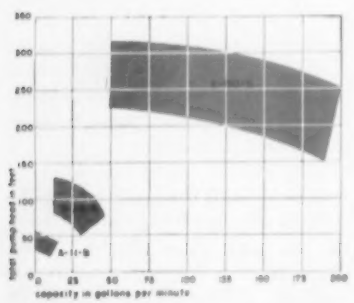
Westinghouse Canned Motor Pumps

available for immediate shipment

For high-temperature, radioactive fluids for nuclear reactors;
For organic fluids and slurries;
For pressurized controlled-circulation systems;
Westinghouse "canned" motor-pumps, tested and in constant use in many plants for over five years, offer these advantages.

- *Suitable for hot standby operation.
- *No injection water sealing required.
- *Corrosion resistant alloys in all pumped fluid lines.
- *No seal maintenance. *No bearing lubrication.
- *No leakage. (No external shaft seals; suction and discharge nozzles welded in line).

Three models of these high efficiency, zero leakage pumps are now being stocked for *immediate shipment.*
Order your immediate requirements now, or write for additional information: WESTINGHOUSE ELECTRIC CORPORATION, P.O. Box 868, Pittsburgh 30, Pennsylvania. J-57018



PERFORMANCE CHARACTERISTICS

Pump Models	A-11-B	A-30-B	A-150-D
Hydraulic Characteristics			
max. suction temp. °F	600	600	650
max. system pressure, psi	2500	2000	2500
net positive suction head required, feet	4	5	12
Electrical Characteristics			
line	220/60/3	220/60/3	440/60/3
rated kw input	4	5.75	17.0
amperes per line	2.7	20.0	25.0
Dimensions and Weights (not to be used for construction)			
overall height	11½"	27⅛"	32⅞"
max. diameter	8⅝"	11"	16⅝"
suction nozzle, pipe size	¾"	1½"	3"
discharge nozzle, pipe size	½"	1¼"	2½"
weight, pounds, (approx.)	60	265	1025

Thirteen other standard models are assembled to order, and special ratings can be built to your specifications.

YOU CAN BE SURE...IF IT'S Westinghouse

Electrostatic Accelerator

This accelerator, designed primarily for food and plastic irradiation, affords positive-ion current up to 1 ma or electron current to 3 ma. Maximum voltage is 600 kv.—S.A.M.E.S., Grenoble France; U. S. distributor: D. Gignous, 50 Broadway, New York 4.

Coating Protects Lab Walls

A newly-developed material seals laboratory walls from radioactive salt deposits. The material—Ceramix—is used at Brookhaven National Laboratory to cover walls of a building housing water-treatment units for processing uranium fuel elements. It forms a smooth, seamless, highly-glazed surface from which hot water will remove contamination. Ceramix is available in eight basic colors; costs less than ceramic tile.—Preco Chemical Corp., 84 County Court House Rd., Garden City Park, N. Y.

Gamma Milker. Unit supplies short-lived γ radioactive material for measuring fluidized solid or liquid flow

rates (NU, May '57, p. 122). Automatic piston arrangement injects radioisotope and flushing solutions; sealed ion exchange resin unit contains parent Cs^{137} that furnishes Ba^{137} to injection system.—Tracerlab, Inc., 130 High St., Boston 10, Mass.

NEW MATERIALS

Ceramic-Like Glass

Pyroceram, newly developed polycrystalline oxide made by turning non-crystalline glass into crystalline material, is said to be "harder than steel, lighter than aluminum and nine times stronger than plate glass." Material might be used in heat exchangers or in high-lead-content formulation for shielding windows. Material keeps its strength at 1300° F; has flexural strength up to 40,000 psi; is gas-tight. Electrical properties are extremely low at high frequencies and temperatures.—Corning Glass Works, Corning, N. Y.

BeO Crucible Wash

Graphite crucibles used in melting uranium-base alloys are treated with beryllium-oxide crucible wash. BeO-treated crucibles can hold carbon content to ~100 parts/million compared with previous 1% carbon pickup. This coating is considered advantageous when melting U-Nb and U-Mo alloys; it has not proven suitable for melting U-Zn alloys, where Zr content is >4%.—Beryllium Corp., Reading, Pa.

Zirconium

Reactor and commercial-grade Zr are available in form of platelets, and irregular flakelike pieces about size of dimes and quarters. Platelets are reportedly superior to ordinary sponge form since they are non-pyropheric, nonhygroscopic and extremely pure. Depending on quantity, price is $4.75–$6.50/lb for hafnium-free Zr sponge or platelets, as compared with former $12/lb.—U. S. Industrial Chemicals Co., 99 Park Ave., New York 16, N. Y.

Plastic fluors. Polystyrene with p-terphenyl and tetraphenylbutadiene is available in rod forms 3–18 in. in diameter, lengths up to 36 in. Decay time is ~4×10^{-9}.—Cadillac Plastic & Chemical Co., 15,111 Second, Detroit 3, Mich.

It's just part of the Victoreen story...

RELIABLE

REMOTE AREA MONITORING SYSTEMS

RELIABLE systems for remote area monitoring—*by Victoreen*. That's just part of Victoreen's radiation monitoring story.

For we're in production and can ship proven remote area systems to AEC requirements for radiation monitoring from a control center.

Get the full story on Victoreen's monitoring systems. We make them for air, gas, water, sewage, etc. That's *Victoreen*—the name that *means* radiation detection, monitoring, and *reliable* protection.

AA-6784

Request your copy of Form 3045a (remote area monitoring systems).

The Victoreen Instrument Company

Instruments Division
5806 Hough Avenue, Cleveland 3, Ohio

WORLD'S FIRST NUCLEAR COMPANY

SCINTILLATION PHOSPHORS

introducing

NE 400

for new simplicity and efficiency in neutron detection

This is a new type boron polyester composition with ZnS (Ag) activator.

- Excellent neutron to gamma response ratio
- High detection sensitivity
- Supplied in thin disks of various diameters
- Also available with enriched B^{10}

PLASTIC PHOSPHOR

NE 102

Our new plastic scintillator possesses an extremely high light output (60–65% of anthracene). It provides superior performance at high counting speed, with maximum efficiency and greatest economy. Available in any size or shape.

LOADED LIQUID SCINTILLATORS

In bulk or encapsulated containing Pb (for x-ray sensitivity), Gd, B or Cd for neutron detection, and Scintillating Gels for internal counting.

SCINTILLATION CHEMICALS

Wide range of highest purity materials.

where research COUNTS

NUCLEAR enterprises ltd.

1750 Pembina Highway
WINNIPEG 9, CANADA

Associate Co.:
Nuclear Enterprises (G.B.) Ltd.
Bankhead Medway, Sighthill, Edinburgh 11, Scotland.

LITERATURE AVAILABLE

Magnesium and titanium with their mechanical and physical properties. 44 p.—Brooks & Perkins, Inc., 1950 W. Fort St., Detroit 16, Mich.

Glassware catalog TG-15 contains prices on 11,130 laboratory and scientific items. 234 p.—Kontes Glass Co., Dept. P-159, Vineland, N. J.

Pneumatic control valves, pilot-operated poppet-type. 16 p.—Galland-Henning Nopak Division, 2713 South 31 St., Milwaukee 46, Wis.

Van de Graaff particle accelerators for research and industry in Bulletin H.—High Voltage Engineering Corp., Burlington, Mass.

Zirconium and hafnium uses. 12 p.—U. S. Industrial Chemicals Corp., 99 Park Ave., New York 16, N. Y.

Radiochemical price list.—Schwarz Laboratories, Inc., 230 Washington St., Mt. Vernon, N. Y.

Argonaut-like UTR with specifications, cutaway and typical layout for facility arrangement. 16 p.—American-Standard Corp., Redwood City, Calif.

Precipitation hardening of stainless steel in booklet 5.—Electric Steel Foundry Co., 2141 N. W. 25th Ave., Portland 10, Ore.

Basic weight control via thickness gaging for paper industries. 12 p.—Industrial Nucleonics Corp., 1205 Chesapeake Ave., Columbus 12, Ohio.

Crystal lattice models, organic molecular models, safety-glass shields etc.—Arthur S. LaPine & Co., 6001 S. Knox Ave., Chicago 29, Ill.

Typical nuclear power station layout and performance specification of its PWR. 9 p.—Martin International, Baltimore 3, Md.

Radiation gaging of wide variety of sheet materials. 36 p.—Tracerlab, Inc., 1610 Trapelo Rd., Waltham, Mass.

High temperature alloys of 10 high-strength types with engineering properties and fabrication characteristics. 20 p.—Carpenter Steel Co., 3167 W. Bern St., Reading, Pa.

Thermistors—wafer, rod and bead—with specifications and characteristics. 10 p.—Gulton Industries, Inc., 212 Durham Ave., Metuchen, N. J.

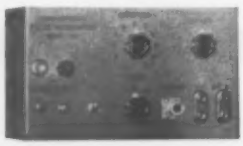
RADIATION INSTRUMENT CO.

MERCURY PULSER

Featuring Versatility and Precision

MODEL 401 $125.00 FOB PLANT

SPECIFICALLY DESIGNED for the NUCLEAR PHYSICS LABORATORY



FAST RISE AND EXPONENTIAL DECAY SIMULATES SCINTILLATION, PROPORTIONAL OR GEIGER COUNTER PULSES FOR TEST AND CALIBRATION OF AMPLIFIERS, PULSE HEIGHT ANALYZERS, SCALERS, ETC.

Rise time: less than 0.003 microsecond.
Decay time: selector switch for 1, 10 or 100 microsecond RC decay
Pulse amplitude: 1 mV to 1 V in 10 steps (from internal supply)
Provision for external battery for pulses up to 45 Volts (continuously variable).
Provision for calibration by external potentiometer.
Polarity switch permits selection of positive or negative pulses.
Output contains only pulses of desired polarity.
Latest improved Western Electric mercury relay. Repetition rate 3600 ppm.
Precision Resistors throughout for high accuracy and stability.
Stable mercury cell, protected by AC relay, lasts for shelf life.

RADIATION INSTRUMENT CO.
P.O. BOX 733 SILVER SPRING, MARYLAND

WASTE DISPOSAL

- RADIOACTIVE
- Explosives
- Pyrophoric Materials
- Poisonous Gases
- Flammable Materials
- Contaminated Equipment
- Toxic Materials
- Acids and Caustics

COMPLETE SEA DISPOSAL
Serving the U.S. Since 1946

Truck pick-up for safely removing dangerous waste is provided by Crossroads. Waste can also be shipped conveniently to Crossroads for disposal from any point in the country using the proper type containers shipped in accordance with ICC regulations. Crossroads will supply containers and shipping instructions, if desired.

Authorized by all necessary Federal, State and Local Authorities

Call, write or wire for complete information.

Crossroads MARINE DISPOSAL CORPORATION
26 T WHARF, BOSTON, MASS.
LAfayette 3-4908

Decontaminate radioactive clothing with American

world's largest manufacturer of laundry and dry cleaning equipment

A complete planning service is available from The American Laundry Machinery Company to help nuclear plants establish efficient decontamination and laundry facilities.

This service, based on more than 89 years' experience in the textile maintenance field, includes detailed drawings, floor plan layouts and complete specifications for each installation. Finished plans show the location, size and floor loads of all machines. Solvent, water, steam, compressed air and electrical requirements are computed, together with size and location of all service connections. Every detail necessary for an efficient, space-saving clothing decontamination department is included.

In addition, American's continuous assistance is always available. Individual representatives, service engineers, local offices and repair depots are strategically located in 84 communities throughout the country.

For complete information on how American serves the atomic energy field, send for Bulletin No. 2642.

You can expect more from

American

The American Laundry Machinery Company, Cincinnati 12, Ohio

"Presenting Lithium" describes properties, uses, research potentials and availability. 15 p.—American Lithium Institute, 32 Nassau St., Princeton, N. J.

"Welding for Nuclear Pumping Applications." 11 p.—Byron Jackson Pumps, Inc., PO Box 2017A, Los Angeles 54, Calif.

Electrometer applications with prices and schematic drawings.—Keithley Instruments, Inc., 12,415 Euclid Ave., Cleveland 6, Ohio.

Ceramic swaged MgO used with power leads, thermocouple wire and leads, etc.—Aero Research Instrument Co., 315 N. Aberdeen St., Chicago 7, Ill.

INDUSTRY NOTES

▶**Universal Transistor Products Corp.** has acquired a new plant in Westbury, L. I.

▶**American Lithium Institute** moved to larger quarters at 32 Nassau St., Princeton, N. J.

▶Construction of new production facilities has started at **Radiation Instrument Development Laboratory,** Chicago, Ill.

▶Joseph W. Greene, director of industrial sales, **Crane Co.,** was elected sales vice-president, a new post. He was succeeded by Charles W. Lovelace, previously manager of the company's valve and fitting department.

▶**Industrial Committee of Brookhaven (L. I.) Township** is promoting the area as a site for firms in nuclear and allied fields. Write: Brookhaven Industrial Committee, Box 232, Patchogue, N. Y.

▶**N. Wood Counter Laboratory** has moved to new, expanded facilities at 1525 East 53 St., Chicago, Ill.

▶Research and development services on contract basis in such fields as ceramics, coatings and surface treatments, etc., will be offered by **Trionics Corp.,** Madison, Wis.

▶**ACF Industries** has established advanced products div sion to manufacture pressure vessels and processing equipment. Nuc'ear Products-Erco will not be affected by the formation of the new division.

▶**Tracerlab** has elected "Homer" S. Myers, to newly created post of marketing vice-president.

Industrial Periscopes

AT
HANFORD
SAVANNAH RIVER
NAVAL RESEARCH LAB
IDAHO FALLS
LIVERMORE
CINCINNATI
OAK RIDGE

Check these advantages

Sharp Definition and Clarity
True Color
Complete Reliability
No Operating Cost

Available with these custom features:

SELECTIVE MAGNIFICATION
REMOTE SCANNING
WIDE FOCUSING RANGE
"NON-BROWNING" OPTICS
BUILT-IN RADIATION SHIELD
INTEGRAL CAMERA ADAPTER
MICROSCOPE RELAY
BINOCULAR EYEPIECES
UNDERWATER DESIGNS

Send for Bulletin 301.

KOLLMORGEN Optical CORPORATION
Northampton, Massachusetts

ANTON...
where precision
COUNTS

ANTON'S
BF_3 COUNTER TUBES...

(enriched, normal or depleted in B^{10}) for detection of either slow or fast neutrons are widely-used in reactor control and monitoring, oil well logging and neutron survey. Available in a wide range of diameters, sensitive lengths and wall thicknesses in 2S aluminum or stainless steel.

ANTON
END MICA WINDOW...

alpha, beta, gamma counters are halogen quenched, stainless steel. Also available with special organic as well as other rare gas fills. Window thicknesses available from 1 mg/cm². Tubes vary from subminiature to standard conventional sizes and are based with standard RMA connectors. JAN types available.

ANTON
THIN WALL...

stainless steel, halogen quenched counter tubes for beta, gamma studies are extremely sensitive and can meet all JAN-MIL specifications. They are the only commercial metal thin wall tubes available with a stainless steel 30 mg/cm² wall which will not dent or collapse. Instruments using groups of these tubes exceed in sensitivity and stability most scintillation units.

ANTON'S PANCAKE TUBES...

are halogen quenched, sensitive beta-gamma detectors with end mica window. These units are designed for low intensity measurement and are widely used in facilities doing low-count work. Flat pancake design offers advantage of large diameter window without large volume and high background count. (Sample changers available.)

Anton high efficiency tubes are Platinized*. This process provides sensitivity beyond that of standard tubes.

Write Dept. NT for complete catalog of Anton nuclear tubes and instruments.

**Reg. pending*

ANTON ELECTRONIC LABORATORIES, INC.
1226 FLUSHING AVE.
BROOKLYN 37, N. Y.
Subsidiary of U. S. Hoffman Machinery Corp.

NEWSMAKERS

Haywood C. Smith, manager of AMF's Raleigh laboratory, has been appointed technical manager in the firm's research and development department. He is succeeded by **James Bolton,** who had held various nuclear engineering posts. AMF's nuclear engineering laboratory has appointed **Robert K. Winkleblack** assistant manager.

Woodman Perine, director of Vitro's Silver Spring laboratory, was elected president of Vitro Engineering Co., replacing **Richard A. North,** who resigned. **Norman A. Spector,** assistant general manager of the engineering division, was named vice-president of Vitro Corp. of America.

AEC's Albuquerque Operations has promoted **Frank C. Di Luzio** to deputy manager, succeeding **George P. Kraker,** retired. Di Luzio has been in the atomic energy program since 1945.

General Electric's aircraft nuclear propulsion department has named **Samuel J. Levine** manager of its Idaho Falls test station. A former consulting engineer at GE's Evendale plant, he replaces **Wayne H. Perry,** who retired.

Lawrence C. Widdoes, technical director since 1955, has been named sales vice-president of Internuclear Co. **Carl F. Leyse,** who joined Internuclear in 1956, becomes technical director.

Beckman Instrument's process instrument division has appointed **Anthony Del Duca** as chief electronics engineer.

A. A. Schulke, formerly engineer in charge of the cyclotron laboratory at Washington Univ., St. Louis, has joined Argonne National Laboratory.

Mallinckrodt Chemical Works has appointed **Edward D. North** as production manager at its Hematite, Mo., nuclear fuel plant. He is slated to relieve **G. W. Tompkin,** who will move over to Mallinckrodt's special metals division.

Stuart McLain has left Argonne National Laboratory where he was a program coordinator to become an independent consultant.

Bell Aircraft's new Lawrence D. Bell research center will have **Everett T. Welmers** as its first director. With Bell since 1944, he will initially supervise its organization and construction.

ISOTOPIC COMPOUNDS
for
TRACER STUDIES

Deuterated solvents of high isotopic purity are now available for use in N.M.R. spectroscopy and other applications:—

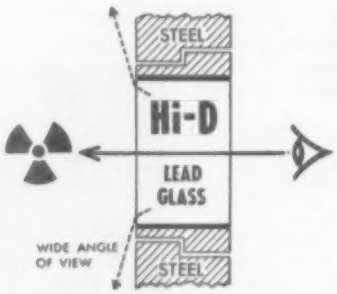
• Acetone-d	99.5%
• Chloroform	99.0%
• Benzene-d_6	99.0%
• Toluene-d_8	98.0%
• Cyclohexane-d_{12}	98.0%
• Toluene-α-d_3	98.0%
• 3-Pentanone-d_{10}	98.0%

We can supply the widest range of deuterated organics available from any source. These include acids, alcohols, halogen derivatives, hydrocarbons, aldehydes, ketones and organo-metallics.

We will welcome your enquiries also for carbon-14 compounds, particularly those requiring special synthesis. Enquiries should be addressed to:—

Chemical Development Department
MERCK & CO. Limited
560 DeCourcelle Street
Montreal 30, Que., Canada

Hi-D®
LEAD GLASS WINDOWS
IN STEEL WALLS



Hi-D Lead Glass Windows provide clear, direct, wide-angle, binocular vision through heavy gamma-shielding walls. Lead equivalent 0.55; steel, 1.0

LARGER SIZES NOW AVAILABLE

Send for circular GS-4

PENBERTHY INSTRUMENT CO.
4201 6th AVE. SOUTH · SEATTLE 8, WASH.

G. Lloyd Martin has joined National Research Corp. as assistant director of the chemistry department, after serving with Mallinckrodt Chemical Works for the past 10 years.

The Council for Economic & Industry Research has appointed **Jack Moshman** director of its mathematical and statistical services division and **William Orchard-Hays,** director, computer services division. Before joining the Council, which offers computation services in reactor design, Moshman was with the AEC, Orchard-Hays with the Rand Corp.

American Society for Testing Materials elected **Richard T. Kropf,** of Belding Heminway Co., New York, president, and **F. L. LaQue,** International Nickel Co., New York, vice-president.

Eugene M. Zuckert, former AEC commissioner, was elected a director of Nuclear Science & Engineering Corp; board chairman is **Gordon Dean.**

James R. Gilbreath has been appointed assistant director of Argonne National Laboratory. With ANL since 1944, he was most recently executive assistant to director **Norman Hilberry.**

Westinghouse named **Victor J. Kropf** to the newly-created post of sales manager, atomic fuel department.

Ralph Carlisle Smith, formerly assistant director of the Los Alamos Scientific Laboratory, was appointed assistant to the president of ACF's Nuclear Products-Erco.

National Science Foundation has named **Robert L. Butenhoff** to be a program director in its office of scientific information. He had been with AEC's Radiation instruments branch.

Bernard G. E. Stiff, previously with High Voltage Engineering, is the new manager of United Shoe Machinery's atomic power department.

James N. Landis, vice-president in charge of commercial atomic energy for the Bechtel Corp., was nominated president of the American Society of Mechanical Engineers, will be installed in December.

Albert S. Jameson, project engineer on Argonne National Laboratory's EBWR has joined General Nuclear Engineering Corp.

NRD PORTABLE MONITORS

FAST NEUTRON SURVEY METER
to detect health hazards

NRD offers survey meters for many needs

BETA-GAMMA MONITOR

"CUTIE PIE" SURVEY METER

SAMSON SURVEY METER

NRD Model E2 fast neutron survey meter is a rugged, accurate, portable instrument designed for health hazard survey where fast neutron radiation is encountered or suspected. Response is tissue equivalent. The instrument covers a wide range of intensities. The lightweight probe weighs only 17 ounces. The circuit and meter case (6½ lbs.) may be carried by shoulder strap or handle. Gamma background is effectively eliminated by a discriminating count rate meter.

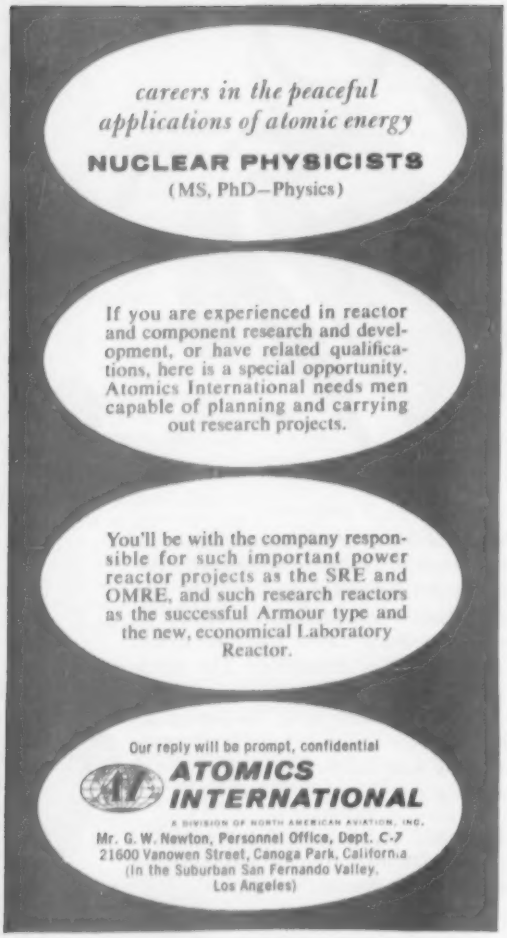
The instrument, which uses transistors extensively, is extremely free of maintenance problems. Batteries are easily replaced.

SPECIFICATIONS AND DESCRIPTIVE LITERATURE ON THESE INSTRUMENTS AVAILABLE ON REQUEST

NRD INSTRUMENT CO. a subsidiary of
nuclear corporation of america, inc.

SALES OFFICES:

Nuclear Consultants, Inc. 33-61 Crescent St. Long Island City 6, N. Y.
Nuclear Corp. of Amer. 9842 Manchester Rd. St. Louis 19, Mo.
Nuclear Corp of Amer. 4754 W. Wash. Blvd. Chicago 44, Ill.
Isotope Specialties Co. 703 S. Main St. Burbank, Calif.
Nuclear Corp. of Amer. Box 7433, Sta. C Atlanta 9, Ga.
Export Dept. 431 Fifth Ave. New York 16, N. Y.
X-Ray & Radium Ind., Ltd. Toronto, Ontario and other Canadian cities.


careers in the peaceful applications of atomic energy
NUCLEAR PHYSICISTS
(MS, PhD—Physics)
If you are experienced in reactor and component research and development, or have related qualifications, here is a special opportunity. Atomics International needs men capable of planning and carrying out research projects.
You'll be with the company responsible for such important power reactor projects as the SRE and OMRE, and such research reactors as the successful Armour type and the new, economical Laboratory Reactor.
Our reply will be prompt, confidential
ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.
Mr. G. W. Newton, Personnel Office, Dept. C-7
21600 Vanowen Street, Canoga Park, California
(In the Suburban San Fernando Valley, Los Angeles)

NUCLEAR CALENDAR

Aug. 7–9—Sixth annual conference on industrial applications of X-ray analysis, Denver Research Institute (*Albany*). Latest developments in X-ray absorption, diffraction and fluorescence analysis. Contact James P. Blackledge, DRI, Univ. of Denver.

Aug. 12–15—First National Conference on Heat Transfer, ASME and AIChE, at Penn State Univ. Contact Prof. G. M. Dusinberre, mechanical engineering dept., Penn State, University Park, Pa.

Aug. 19–24—High-energy physics symposium, Oak Ridge National Laboratory and Institute of Nuclear Studies. Topics include theory of elementary particles and their interactions, experiments with nuclear-emulsion techniques, bubble chambers and counters. Contact University Relations Division, ORINS, P.O. Box 117, Oak Ridge, Tenn.

Aug. 20–21—Third biennial electron beam symposium, General Electric X-ray dept., Milwaukee. Reports on radiation equipment, applications and economic evaluation of processes in chemicals, plastics, petroleum and food fields. Contact J. J. Ludwig, GE X-ray dept., 4855 Electric Ave., Milwaukee 1.

Aug. 20–22—Conference on liquid scintillation counting, Northwestern Univ., at Technological Institute, Evanston, Ill. Coincidence counters, single-channel counters, chemistry of liquid scintillators, applications in biology, medicine, industry, archaeology, physics, chemistry and engineering. Contact F. Newton Hayes, Los Alamos, N. M.

Sept. 8–13—Conference on water purity requirements and water conditioning equipment of nuclear power plants. American Chemical Society, New York. Contact ACS, 2 Park Ave., New York 16, N. Y.

Sept. 9–13—Twelfth annual Instrument-Automation conference and exhibit, ISA, Cleveland (*Cleveland Auditorium*). Contact H. S. Kindler, ISA, 313 Sixth Ave., Pittsburgh 22, Pa.

Sept. 9–13—International conference on nuclear structure, co-sponsored by Unesco and International Union of Pure and Applied Physics, at Rehovoth, Israel. Contact Amos de Shalit, nuclear physics department, Weizmann Institute of Science, Rehovoth.

Sept. 9–13—International conference on neutron interactions with the nucleus, Columbia Univ., New York. Participants include I. I. Rabi, W. B. Lewis, H. A. Bethe, D. J. Hughes, E. P. Wigner. Contact R. W. Siegel, Phys-

ics dept., Columbia Univ., New York 27.

Sept. 9–20—International conference on radioisotopes in scientific research, Unesco, in Paris. Purpose: exposition and discussion of new ideas or methods for utilization of radioisotopes in scientific research. Plenary sessions on production and measurement techniques, section meetings in physical and biological applications. Contact Dept. of Natural Sciences, Unesco, 19 Avenue Kléber, Paris 8e.

Sept. 22–27—Colloquium on mesons and recently-discovered particles, International Union of Pure and Applied Physics, in Venice. Contact Prof. Eligio Perucca, director, Politecnico, Turin, Italy.

Oct. 6–12—Ninth atomic energy course for management, National Industrial Conference Board, in Chicago (*Hotel Moraine-on-the-Lake*), Highland Park, Ill. Contact John McMahon, NICB, 460 Park Ave., NYC.

Oct. 7–9—Thirteenth annual National Electronics Conference, Chicago (*Sherman*). 100 technical papers, 240 exhibits. Contact F. A. Judd, NEC, 84 E. Randolph St., Chicago 1.

Oct. 7–12—French Metallurgical Week, French Metallurgical Society, Paris. Contact J. Pomey, president FMS, 25 rue de Clichy, Paris 9.

Oct. 28–Nov. 1—Autumn Nuclear Week in New York. Included are: **28–30th**, fourth annual meeting of the Atomic Industrial Forum (meetings *Plaza* and *Coliseum;* banquet *Waldorf*). **28–31st**, third annual Trade Fair of the Atomic Industry, sponsored by AIF (*Coliseum*). **28–30th** second winter meeting of the American Nuclear Society (*Henry Hudson*). **31st**, AEC-ANS-AIF reactor safety conference. And IRE's Professional Group on Nuclear Science holds fourth annual meeting **31–1st** (*Henry Hudson*).

Nov. 2–8—Second world metallurgical congress, American Society for Metals, Chicago. Contact W. H. Eisenman, congress secretary general, ASM, Cleveland. **3–8th**, second international conference on nondestructive testing. Contact G. H. Tenney, 704 47th St., Los Alamos, N. M.

Nov. 7–8—Seventh annual symposium, Philadelphia section of Instrument Society of America, Philadelphia (*Sheraton*). Subject: new ideas in instrumentation evolved from nuclear developments. Instruments Fair included. Contact Warren Brand, Conoflow Corp., 2100 Arch St., Philadelphia 3.

Dec. 24–26—Conference on nuclear sizes and density distribution, National Science Foundation, Palo Alto, Calif. Contact Robert Hofstadter, Stanford Univ., Palo Alto.

PREFERRED

During the past 5 years, the proven performance of the EKCO Model 1079-C Vibrating Reed Electrometer has made it preferred by actual users, both here and abroad.

Low in cost, compact, rugged and easily serviced; its high, full-scale sensitivity and inherent stability makes the EKCO Model 1079-C ideal for all applications involving small current and voltage measurements.

STABILITY:	± 1 mv, day-to-day.
SENSITIVITY:	0.03 μμa full-scale reading @ max.
RANGES:	0-30, 0-100, 0-300, 0-1000 mv.
INPUT:	Internal, switch-controlled, 10^{8}, 10^{10}, 10^{12} ohm resistors.
OUTPUT:	Operates with 1 ma or 100 mv recorder.
POWER:	110/120 or 200/250 v, 40/60 cps, 40 w.
WEIGHT:	Only 29 lbs., complete with cables.

Write TODAY for Bulletin L-572 for complete data

AMERICAN TRADAIR CORP.
34-01 30th Street, Long Island City 6, N. Y. • Dept. N7
U.S. SALES & SERVICE for
EKCO ELECTRONICS, LTD., Essex England

FOR PRODUCT INFORMATION IN THE NUCLEAR INDUSTRY TURN TO THE . . .

NUCLEONICS BUYERS' GUIDE

(IN THE NOVEMBER ISSUE)

A McGRAW-HILL PUBLICATION
330 WEST 42ND STREET · NEW YORK 36, N. Y.

JUST OFF PRESS

Nuclear Power Engineering

Gives a clear explanation of nuclear power plants—design, construction, and operation. From essential fundamentals of physics to detailed design features of specific power reactors, every important aspect is covered. In addition to engineering methods, book includes helpful information on components, radiation and its effects, plant sites, and economics of production. By H. C. Schwenk, Henry Pratt Co., and R. H. Shannon, United Engrs. & Constrs., Inc. Ed. by B. G. A. Skrotzki, Engg. and Mgt. Ed., Power. 344 pp., illus. $6.50

Nuclear Engineering

JUST OUT! **Whether your nuclear design work takes you into power cycles, fluid flow, heat removal, reactor shielding, or other areas of the field, you will find in this book latest engineering information for solving a wide range of problems. Prepared by a staff of experts, it takes up such topics as mathematical analysis of plastic flow in thermal stress, design of orifices for protection of parallel coolant channels, and others. Edited by C. F. Bonilla, Chairman, Nuclear Engineering Comm., Columbia U. 841 pp., 272 illus., $12.50**

Engineering Electronics

JUST OUT! **Gives you sound knowledge of electronics theory for effectively designing and working with modern electronic equipment for industry. From basic facts on vacuum tubes as circuit elements to more advanced topics such as switching circuits, computing amplifiers, power rectification, and electronic motor control, this big, 666-page book covers a broad area in a way that is *clear, concise,* and *useful*. By John D. Ryder, Dean of Engrg., Michigan State U. 666 pp., 796 illus., $9.50**

Building An Engineering Career

Brings you helpful guidance in choosing the kind of engineering career in which you will be successful. Plainly and thoroughly explains the scope of each engineering branch, the kind of work involved, the chief accomplishments of each, income and job possibilities, and gives pointers on preparing for such a career. By C. C. Williams. 3rd Ed. rev. by E. A. Farber, U. of Fla. 297 pp., 60 illus., $4.75.

10 DAYS' FREE EXAMINATION

McGraw-Hill Book Co., Inc. Dept. Nu-7
327 W. 41st St., New York 36, N. Y.

Send me the book(s) checked below for 10 days' examination on approval. In 10 days I will remit for book(s) I keep, plus few cents for delivery costs, and return unwanted book(s) postpaid. (We pay delivery costs. If you remit with this coupon—same return privilege.)

- ☐ Schwenk et al—Nuclear Power Engrg., $6.50
- ☐ Bonilla—Nuclear Engineering, $12.50
- ☐ Ryder—Engineering Electronics, $9.50
- ☐ Williams—Building Eng. Career, $4.75

(PRINT)

Name .....
Address .....
City ..... Zone .... State .....
Company .....
Position .....

For price and terms outside U.S. write McGraw-Hill Int'l, N.Y.C. Nu-7

Nuclear Navy

(Cont. from p. 71)

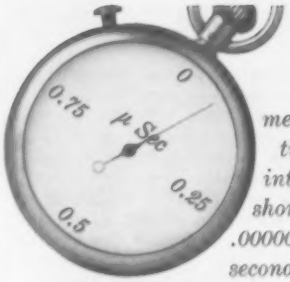
maintenance purposes. "Since nuclear plants are capable of really continuous operation, a much greater degree of self-supporting maintenance at sea must be possible fully to exploit continued operations," he points out.

"Purchasing personnel must work hand-in-hand with engineering personnel concerning the specifications of unusual components, selection of source, and follow-up of progress," Shugg says. "We have learned the hard way that normal or routine field inspection and in-yard receipt inspection cannot be relied upon." EB has added much new test gear, metallurgical and other.

There are other special problems besetting the purchasing agent engaged in nuclear power work, according to Harlan Turner Jr., assistant chief naval architect at Electric Boat. An atomic purchasing agent has to deal with small quantities and can give no assurance to the supplier regarding repeat orders, since there are so few repeat orders in this period of research and development—of rapid change. As a counter to this, however, is an inducement; the prospect of rapid expansion of the industry that may ultimately lead to large quantities.

Another trouble is that items often are called for that require development work. Unless they are very large, there is not likely to be any contract to encourage the supplier to carry out the development work, nor—often—even any assurance that he will get the order if he does do the developing, because in so many cases the job is government-sponsored and subject to the law requiring competitive bidding. This has been a frequent source of bitterness and disenchantment.

Electric Boat now has a staff of full-time expediters who do nothing but stay on the telephone or out on the road working with suppliers on nuclear submarine components—a new activity, since before everything was bought off the shelf. The expediters use only friendly persuasion—"no clobbering"—and in fact much of their attention is directed inward: they find out what information the supplier is missing from EB, then turn their efforts inward to get the answers. Design of a component is ordered before fabrication, and expediters must first see that the supplier furnishes plans on time, then expedite internally to get the plans approved for fabrication.



measure time intervals short as .00000000004 seconds

Milli-Microsecond
time-to-pulse-height converter

Model TH-300... Applications: Neutron time-of-flight studies, half-life determinations in short-lived isotopes, fast coincidence studies, short-time decay in isomeric states.
Domestic price $750. FOB, Factory.

Write for technical data sheet # N-2

Eldorado Electronics

1401 Middle Harbor Road
Oakland, California

AIRMATIC
Pneumatic Tube Systems for Sample Irradiation

Specially engineered and manufactured for providing fast and safe transmission of materials within the reactor core as well between the core and laboratory, test booth, etc.
"Rabbits" of fiber, magnesium or plastic handle any type of test material and are propelled by vacuum or a combination of vacuum and pressure.
We engineer and manufacture all types of Pneumatic Tube Systems for overall plant communications from Manual Systems to Fully Automatic Systems

For Further Information Call or Write:

AIRMATIC SYSTEMS CORP.
378 Bergen Blvd., Fairview, N. J.
Phones: N. J.—WHitney 5-0475
N. Y.—OXford 5-6088

WHERE - TO - BUY

This Where-To-Buy section has been established for manufacturers desiring advertising in space units smaller than the minimum run of book display space. Space is available in this section in units from one to four inches. Every advertisement is indexed. The section can be used economically to promote new product users and users, establish new sales outlets, reach all buying influences at an extremely low cost.

Rates are per inch per insertion. Contract rates are based on the use of 6 or 12 issues within the contract year, and as specified below:

1 Time	*6 Times*	*12 Times*
$21.75	$20.25	$18.75

Send inquiries to: Nucleonics—Where-To-Buy, Post Office Box 12, N. Y. 36, N. Y.

RARE EARTHS

Highest purity compounds for fundamental research in physics and chemistry.

Write for information of rare earth compounds.

The Gows Chemical Co., Inc.
P.O. Box 443, Laramie, Wyoming

URINALYSIS SERVICE

NSEC laboratories are staffed and equipped to perform routine and emergency urinalysis for:

- Total uranium
- Enriched uranium
- Plutonium
- Polonium
- Fission products
- Gross activities
- Other radioactive isotopes

Nuclear Science and Engineering Corp.
Subsidiary of Norden-Ketay Corporation
P.O. Box 10901, Pittsburgh 36, Penna.

THORIUM
High Purity-Crystal-Bar

Crystal-bar thorium of the highest purity now obtainable is available from Metal Hydrides Incorporated. A product of the van Arkel-de Boer process, quality is typical of crystal-bar metal. Oxygen is less than 50 PPM, nitrogen less than 20 PPM, and carbon less than 40 PPM. Most metals below 2 PPM or not detectable; the exceptions being aluminum less than 20 PPM, iron approximately 30 PPM, and copper less than 20 PPM.

Metal Hydrides Incorporated
Congress Street, Beverly, Massachusetts

DRY BOXES
GLOVE BOXES

with atmosphere controls of stainless steel and transparent plastic. Custom metal and plastic fabrication. P. M. Lennard Co., Inc.
P.O. Box 56, Village Station, New York 14, N. Y.
Phone STerling 9-2420

HEALTH PHYSICS SERVICES
1109–13 Low Street Baltimore 2, Md.
FILM BADGE SERVICE
BETA—GAMMA—NEUTRON SERVICE
Report sent out within 5 Days

GLOVES

Bellows accordion type or straight sleeve neoprene, lead rubber or surgeon rubber . . . complete "O" ring systems for field assembly. IMMEDIATE DELIVERY.
P. M. Lennard Co., Inc.
P.O. Box 56, Village Station, New York 14, N. Y.
Phone STerling 9-2420

EMPLOYMENT OPPORTUNITIES

The Advertisements in this section include all employment opportunities—executive, management, technical, selling, office, skilled, manual, etc.

Positions Vacant | **Civil Service Opportunities** | **Employment Agencies**
Positions Wanted | **Selling Opportunities Wanted** | **Employment Services**
Part Time Work | **Selling Opportunities Offered** | **Labor Bureaus**

NATIONAL COVERAGE

—RATES—

DISPLAYED

The advertising rate is $16.75 per inch for all advertising appearing on other than a contract basis. Contract rates quoted on request.

An advertising inch is measured ⅞" vertically on a column—3 columns—30 inches to a page.

Subject to Agency Commission.

$1.00 per line, minimum 3 lines. To figure advance payment count 5 average words as a line.

UNDISPLAYED

Positions Wanted—The rate is one-half of the above, payable in advance.

Box Numbers—counts as 1 line.

Discount of 10% if full payment is made in advance for 4 consecutive insertions.

Not subject to Agency Commission.

Send NEW ADS or inquiries to Classified Advertising Division of NUCLEONICS, P. O. Box 12, New York 36, N. Y. August issue closes July 3rd

PHYSICIST required by
SASK. DEPT. OF PUBLIC HEALTH

SALARY RANGE: $496–$595 per month

REQUIREMENTS: Completion of a four years honours course in physics and a graduate degree in physics, considerable experience in radiation physics or in a related field and, preferably, experience and interest in isotopes. The appointee will work in the Allan Blair Memorial Clinic in Regina, Sask., Canada. Equipment and facilities include superficial and medium voltage X-ray apparatus, an isotope laboratory and a cobalt 60 rotating apparatus which will be installed in the course of the next few months.

HOW TO APPLY: Write to Public Service Commission, Legislative Bldg., Regina, Sask., Canada for application forms and further information. Applicants should refer to competition #4737.

ENGINEERS

If you have been looking for an Employment Agency that is skilled in the STATE OF THE ART of Technical Recruitment and RELIABILITY OF INFORMATION concerning positions, why not communicate with us at once! ALL POSITIONS FEE PAID.

FIDELITY PERSONNEL SERVICE
1218 Chestnut St. Phila. 7, Pa.
Specialists in Aviation, Electronics and Nucleonics

REPLIES (Box No.): Address office nearest you
c/o This publication Classified Adv. Div.
NEW YORK: P. O. Box 12 (36)
CHICAGO: 520 N. Michigan Ave. (11)
SAN FRANCISCO: 68 Post St. (4)

Position Vacant

Opening in the Department of Radiology, Isotope Laboratory, for responsible individual. Academic appointment, research opportunity. Position and salary commensurate with experience and background. Minimum requirements B.S. in Physics. Submit replies to W. W. Moos, Ph.D., University of Illinois, 840 S. Wood Street, Chicago 12, Illinois.

Positions Wanted

Agricultural Isotope Research—Ph.D. chemist with strong background in physics, physical chemistry, and mathematics. Nine years experience in radioisotope studies. Over 15 publications. Academic only. PW-5296, Nucleonics.

CHEMIST

Desires Nuclear Energy Field in East. BA LaSalle College 1953. Three years' experience Nuclear Weapons Technology with Armed Forces Special Weapons Project. Naval Officer; Military release date 1 Dec. 57.

PW-5294 Nucleonics
520 N. Michigan Avenue, Chicago 11, Ill.

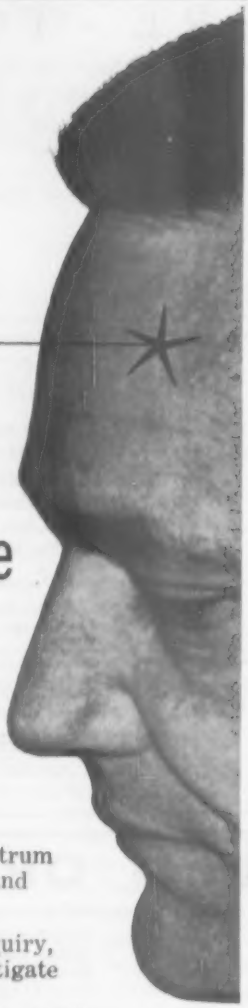
Positions Wanted

Electrical Engineer, BSEE 1951, Age: 27, single, 4 years diversified experience in nuclear field including reactor field construction. 21 month military service as fire control instructor. Desire position permitting foreign employment and/or world travel. Salary open. PW-5210, Nucleonics.

Special Service

Laboratory Equipment Repair Co. 1810 W. Ogden, Chgo. 12, Ill. AO-Beckman-B&L-Coleman-Klett-Leitz.

Research Engineers



Marquardt offers

A Professional Climate

which encourages original and independent research

Marquardt Aircraft, the leader in ramjets—"Powerplant of the Future"—offers research engineers a veritable spectrum of advanced projects; advanced in time, and in technological significance.

In an environment which permits free inquiry, Marquardt engineers and scientists investigate many aspects of supersonic propulsion; including ramjet, turbojet and rocket motors and Aircraft Nuclear Propulsion. This work is achieving a new understanding of the aerodynamic, thermodynamic, and chemical behavior of various elements of these propulsion systems and their exotic fuels.

In other areas, such as the broad field of New Products Research, Marquardt engineers investigate projects reaching far into the future. In keeping with the company's reputation for products which are in the forefront of advancing technology, these projects are timed for tomorrow.

Research engineers with creative vision are invited to investigate the opportunities at Marquardt. Please write Jim Dale, Professional Personnel, 16559 Saticoy Street, Van Nuys, California.

marquardt AIRCRAFT CO.

VAN NUYS, CALIFORNIA — OGDEN, UTAH

FIRST IN RAMJETS

ENGINEERS

Ground Floor Opportunities for Promotion Minded Engineers in Nuclear Reactor Field

A new Technical Production Operation has been formed at General Electric's expanding Aircraft Nuclear Propulsion Department, to handle production engineering and control of highly technical, chemical and metallurgical processing of nuclear components.

Positions immediately available at all levels in production of

- Shielding
- Fuel Elements
- Control Materials

Production background in physical metallurgy or chemical engineering desired.

Starting salaries are fully competitive, and backed by a comprehensive benefit program that includes Insurance, Pension and Stock Bonus Plans.

And at General Electric your professional development is encouraged through in-plant technical and managerial training and a Full Tuition Refund Plan for graduate study.

Choice of two locations:

Cincinnati, Ohio
Idaho Falls, Idaho

Relocation Expenses Paid

Why not take time out today to tell us about yourself—you'll hear from us in less than a week.

Write in confidence, stating salary requirements to location you prefer:

GENERAL ELECTRIC

J. R. Rosselot
P. O. Box 132
Cincinnati, Ohio

L. A. Munther
P. O. Box 535
Idaho Falls, Idaho

Destination: Leadership

Every week, scientists and engineers from all over the country arrive at Argonne to begin their work at this center of research and development studies in nuclear science. They have selected Argonne, recognizing the value of an organization whose interests include physics, chemistry, biology, metallurgy, applied mathematics and electronics; as well as nuclear, chemical, and mechanical engineering.

Argonne
NATIONAL LABORATORY
Operated by the University of Chicago under a contract with the United States Atomic Energy Commission

Inquiries Invited

METALLURGISTS • CHEMICAL ENGINEERS
MATHEMATICIANS • PHYSICISTS • CHEMISTS
METALLURGICAL ENGINEERS • MECHANICAL ENGINEERS
ELECTRICAL ENGINEERS • HEALTH PHYSICISTS
PLANT ENGINEERS • SAFETY ENGINEERS
INDUSTRIAL HYGIENISTS

PROFESSIONAL PERSONNEL OFFICE
P. O. BOX 299 • LEMONT, ILLINOIS

SENIOR RESEARCH PHYSICIST
SENIOR ELECTRONICS ENGINEER

The new Central Research Laboratory of Continental Can Company has several opportunities for versatile scientists and engineers with advanced degrees and industrial experience to pioneer in the application of acoustics, optics, mathematical physics, electronics, rheology, solid state physics, and other fundamental fields to long-range industrial problems in such areas as energy conversion, automatic controls, instrumentation, and communications.

The wide variety of materials manufactured or fabricated at high speeds by Continental includes metals, glass, plastics, paper, fiber, and combinations of these, and provides opportunities for advancing knowledge in many new fields. Research facilities of the Company's new Chicago laboratories are believed second to none, and are located so as to allow staff members to live in some of the finest western and southern suburbs of the city. Proximity to the John Crerar Library, Armour Research Foundation, the University of Chicago, Argonne National Laboratory, and many leading manufacturers of scientific and technical equipment enhances professional development and expedites accomplishment in chosen fields.

Staff members will be granted the full degree of individual recognition attainable in a total staff of 100 covering the fields of chemistry, metallurgy, engineering, and physics, and will have the opportunity to work closely with scientists and engineers in the other fields. Salaries and other benefits meet the highest industrial standards.

Please write, giving a brief resume of qualifications, to Director Physics Research, Central Research and Engineering Division, Continental Can Co., 7622 S. Racine Avenue, Chicago 20, Illinois.

ATOMIC POWER DEVELOPMENT

Engineering and Research Openings for

- **REACTOR PHYSICS**
- **REACTOR SHIELDING**
- **REACTOR CONTROL AND INSTRUMENTATION**
- **REACTOR KINETICS**

SALARY commensurate with ability and experience.

Men experienced in careers in the peaceful application of atomic energy are needed to assist Atomic Power Development Associates . . . renowned for work on the fast breeder type reactor. This group supported by major industrial and utility companies is in the forefront of pioneering developments in the use of atomic energy for electric power production.

For further information write

P. Amerman

ATOMIC POWER DEVELOPMENT ASSOCIATES, INC.
1911 First Street
Detroit 26, Michigan

NUCLEAR ENGINEERS

and

PHYSICISTS

Needed for Engineering Consulting Service in UNITED STATES and EUROPE

For further information about job openings, send resume to

Internuclear Company
7 N. Brentwood Blvd.
Clayton 5, Missouri

RADIOCHEMISTS

A STRATEGIC ROLE IN NUCLEAR POWER

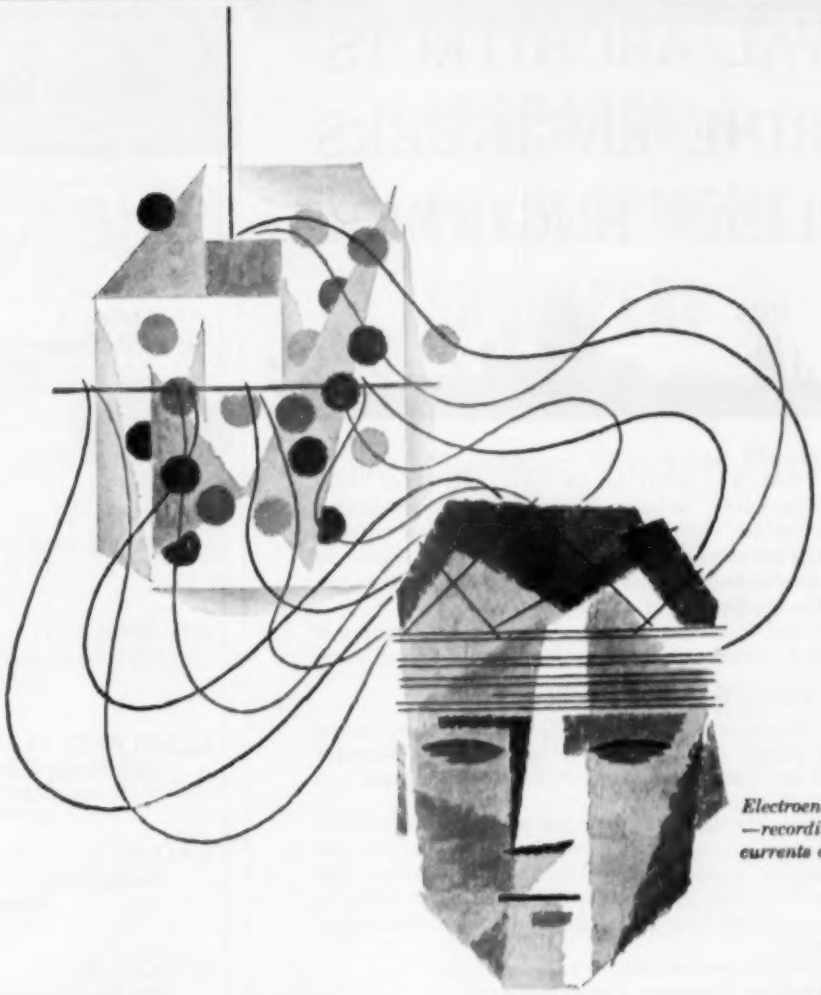
An excellent position is available for a radiochemist with at least a B.S. degree in chemistry, experience in radiochemistry preferred.

At Bettis Atomic Power Division, the radiochemist plays an active part in the research and development of nuclear reactor plants. He will apply nuclear chemistry to the problem associated with nuclear power systems, including the study of intermediate mass and heavy mass nuclides produced in such systems and the development of instrumentation for measuring these nuclides.

Investigate this unusual opportunity at Bettis Atomic Power Division. Send your resume and salary requirements to Mr. M. J. Downey, Dept. A-175, Bettis Atomic Power Division, Westinghouse Electric Corporation, P. O. Box 1468, Pittsburgh 30, Pennsylvania.

BETTIS ATOMIC POWER DIVISION

Westinghouse



Electroencephalography —recording the electric currents of the brain.

WHAT'S YOUR "WAVE LENGTH"?

Some of the most stimulating engineering problems in the world today are waiting for solutions at Honeywell, Brown Instruments Division.

Even the fine engineering staff now at work here needs help.

But the ordinary engineer won't do. Standards are too high, demands too exacting for all but those with extraordinary capacity.

We're interested in you, *if* you think you'd "fill the bill".

Everybody knows Brown Instruments . . . the world's leading designer and producer of industrial instruments. And engineers know the company's reputation for superior treatment . . . in pay, in extras, in the factors that count with an engineer. Many come to us, few are selected, very few leave.

If you're our type of man, we think you'd be happy working here. You don't have to supply a resumé. Just send in your name, address and home telephone number . . . address Mr. Dan Garvey . . . we'll get in touch with you.

Good Company—*at Brown you'll work with such men as Roger S. Hewett, B.S. in E.E., Tufts College. With Brown 18 years, Roger is Section Head of an Application Engineering section on government and institutional instrumentation.*

Honeywell BROWN INSTRUMENTS DIVISION
Wayne & Windrim Avenues • Philadelphia 44, Pa. *First in Controls*

NAVAL ARCHITECTS
MARINE ENGINEERS
NUCLEAR ENGINEERS

The CENTRAL TECHNICAL DEPARTMENT of Bethlehem's Shipbuilding Division, an experienced organization recognized for its technical achievements, offers unusual opportunities to recent college graduates to participate in the latest developments in naval and merchant ship design, including the application of nuclear power.

Specialized training in Nuclear Reactor Engineering is available to a limited number of properly qualified engineers.

CONTRACTS NOW UNDERWAY INCLUDE

Design and Construction of Nuclear-Propelled U. S. Navy Cruiser
Preliminary Design of Nuclear Propulsion Plant for Destroyer
Design and Construction of World's Largest Oil Tankers

If you would like to make full use of your professional training in creative engineering, enjoy easy commuting and have convenient access to New England's educational and recreational facilities, you are cordially invited to write to us. Your inquiry will be considered confidential and acknowledged promptly.

BETHLEHEM STEEL COMPANY
Shipbuilding Division

Please Address C. H. GOLDTHWAITE
Asst. to Technical Manager

CENTRAL TECHNICAL DEPT., QUINCY 69, MASS.

RADIATION CHEMIST

Southern Research Institute needs an experienced radiation chemist to supervise its new 1000-curie cobalt-60 source, and also to head its further expansion into atomic energy activities.

Send resume to:

SOUTHERN RESEARCH INSTITUTE
Birmingham 5, Alabama

QUICK SOLUTION TO MAN POWER PROBLEMS . . .

through the EMPLOYMENT OPPORTUNITIES Section of the publication. The market place for those offering or wanting the services of men on engineering, technical and executive level.

This section offers a quick, effective solution to your man power problems, because its readership is confined to just the type of men you need . . . Waste circulation is avoided . . . You reach only the men you want.

NUCLEONICS
P.O. Box 12
Classified Adv. Div., New York 36, N. Y.

For Rates or Information
About Classified Advertising

Contact The McGraw-Hill Office Nearest You.

ATLANTA, 3
1321 Rhodes-Haverty Bldg.
JAckson 3-6951
M. MILLER

BOSTON, 16
350 Park Square
HUbbard 2-7160

CHICAGO, 11
530 No. Michigan Ave.
MOhawk 4-5800
W. HIGGENS, J. BRENNAN

CINCINNATI, 37
8125 Yorktown Rd.
REdwood 1-3238
G. W. MILLER

CLEVELAND, 15
1510 Hanna Bldg.
SUperior 1-7000
W. B. SULLIVAN

DALLAS, 2
Vaughn Bldg.
RIverside 7-5117
G. JONES

DETROIT, 26
856 Penobscot Bldg.
WOodward 2-1793
W. STONE

LOS ANGELES, 17
1125 W. 6th St.
MAdison 9351
D. McMILLAN

NEW YORK, 36
500 Fifth Ave.
OXford 5-5959
S. T. HENRY, D. COSTER, R. LAWLESS

PHILADELPHIA, 3
17th & Sansom St.
RIttenhouse 6-0670
R. EDSELL, H. BOZARTH

ST. LOUIS, 8
3615 Olive St.
JEfferson 5-4867
W. HIGGENS

SAN FRANCISCO, 4
68 Post St.
DOuglas 2-4600
R. C. ALCORN

SEARCHLIGHT SECTION

(Classified Advertising)

BUSINESS OPPORTUNITIES · EQUIPMENT · USED or RESALE

UNDISPLAYED RATE
$1.80 a line. Minimum 3 lines.

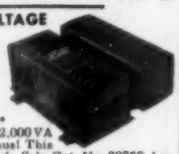
DISPLAYED RATE
$15.90 per inch

ADVERTISING INCH: ½" on one column, 3 columns—30 inches—to a page.

a TERRIFIC BARGAIN in a

SOLA CONSTANT-VOLTAGE TRANSFORMER

Ends fluctuating line voltage!



BIG DISCOUNT OFF...

the factory price at a 1-input 2,000 VA unit! And here's another bonus! This Air Force 2,000 VA overstock, Sola Cat. No. 30768, has 4 inputs! 90-125 V., 190-250 V., 60 cy. or 50 cy. Isolated secondary is constant 115.0 V. ± 1% from no load to full-load of 17.4 amp. So, if you choose, use it as a 220:115 V. step-down. And slash $97.50 off the factory 1-input price! Brand new in original wood box. 4 cu. ft. Ship. wt. 254 lbs. F.O.B. Pasco, Wash. Only **$147.50**

(EXPORTERS: Note choice of 50 cycles.)

THE M. R. COMPANY
P. O. Box 1220-D Beverly Hills, Calif.

PROFESSIONAL SERVICES

OMEGA ENGINEERING CO.

Specialists in engineering and piping design for reactor fluid systems, structural containment, test loops, purification systems and waste disposal systems. Contact Mr. Brodsky.

70 East 45 St., N. Y. 17
Murray Hill 9-7254

ARCHITECT-ENGINEER SERVICES
Mechanical-Electrical-Civil-Structural
All types of installations—All activity levels
VENTILATION CONSULTANTS
Faulty ventilation installations corrected
Access Permittee—Experienced cleared personnel

A. I. BRAYMAN & CO.
27 School St., Boston 8, Mass. Capitol 7-9465

New Advertisements

received by July 3rd will appear in the August issue, subject to space limitations.

Classified Advertising Division
Nucleonics
P.O. Box 12 New York 36, N. Y.

RESEARCH and DEVELOPMENT ENGINEERS and SCIENTISTS

for Nuclear Marine Propulsion

A relatively new and far-reaching field and a major industrial leader — together they offer unparalleled opportunities for men well versed in fundamentals of design and development of nuclear power plants and associated equipment.

The Knolls Atomic Power Laboratory is currently devoting its applied research facilities to the development of two distinct marine propulsion systems — one for the submarine, Triton, the world's largest; and one for the Navy's first nuclear-powered destroyer. Here you'll join nationally prominent engineers and scientists working out the new and challenging technical problems presented by these advanced projects.

Immediate Openings at all levels in:

Stress Analysis • Instrumentation • Mechanical Design
Applied Mathematics • Electronics • Heat Transfer
Theoretical and Experimental Physics • Fluid Flow
Chemistry • Chemical Engineering • Metallurgy

The Knolls Atomic Power Laboratory also offers a full-tuition refund, work-study plan leading to an M.S. at Rensselaer Polytechnic Institute, open to above-average graduates who have received a B.S. degree within the past three years. In addition to this plan, full-time employees may pursue advanced degrees by evening studies with full-tuition refund.

A letter expressing your interest will receive immediate attention. Please address all replies to Mr. A. J. Scipione, Dept. 44-MG.

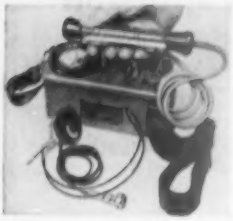
Knolls Atomic Power Laboratory
OPERATED FOR A.E.C. BY
GENERAL ELECTRIC
SCHENECTADY, N.Y.

NMC
INDIANAPOLIS

Precision Nuclear Instruments

THE "NUCLIGUARD" MONITOR

- An area-personnel-equipment monitor
- Preset alarm level from 50-50,000 cpm.
- 3-cycle logarithmic count rate meter,
- AC powered with 3600 cpm test signal
- Beta-gamma GM probe or gamma scintillation detector



LABORATORY SURVEY INSTRUMENTS

- End window, coaxial GM or scintillation detectors
- Watertight and completely shock mounted
- Lightweight, compact and with long battery life
- FCDA approved and tested circuitry and components

Send for Free
NMC CATALOG

Nuclear Measurements Corp.
2460 N. Arlington Ave. • Telephone: LIBERTY 6-2415
INDIANAPOLIS 18, INDIANA
International Office: 13 E. 40th St., New York 16, N.Y.

MOVING?

If you are moving (or have moved), tell us about it, won't you? Your copies of NUCLEONICS will not follow you unless we have your new address immediately. Make sure you don't miss a single important issue . . . and help us make the correction as speedily as possible by giving us your old address, too

NUCLEONICS
Circulation Dept.
330 W. 42nd St., New York 36, N. Y.

INDEX TO ADVERTISERS

JULY, 1957

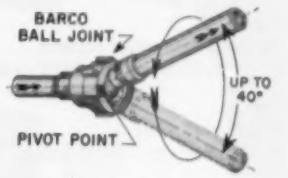
ACF Nuclear Products, Div. of ACF Industries Inc.... 11
AMF Atomics, Inc.....40, 41
Advertising Council..... 10
Airmatic Systems Corp. an I T & T Associate.....126
American Laundry Machinery Co. 121
American Tradiar Corp., Ekco Electronics, Ltd.....125
Anton Electronic Laboratories, Inc.....122
Applied Radiation Corporation..... 50
Atomics International, a Division of North American Aviation, Inc.....124
Atomic Laboratories, Inc... 93
Babcock & Wilcox Co., Atomic Energy Div....34, 35
Tubular Products Div..... 47
Baird-Atomic, Inc....3rd cover
Barco Manufacturing Co...135
Bean & Co., Morris..... 98
Brush Beryllium Co..... 42
Carlson, Inc., G. O..... 31
Central Research Laboratories, Inc. 3
Chempump Corp. 32
Corning Glass Works.....102
Crawford Fitting Company. 85
Crossroads Marine Disposal Corp.....120
Davison Chemical Company 95
Donner Scientific Co.....106
Douglas Aircraft Company. 6
Eldorado Electronics.....126
Federated Metals Division of American Smelting & Refining Company.....113
Ford Instrument Co., Div. of Sperry Rand Corp..... 14
General Electric Co. Atomic Power Equipment Dept. 38, 39
General Mills Mechanical Div..... 8
General Transistor Corp.... 5
Gows Chemical Co., Inc., The 127
Graver Tank & Mfg. Co., Inc. 4

Hamner Electronics Co., Inc. 2nd cover
Harshaw Chemical Co..... 46
Haws Drinking Faucet Co...114
Health Physics Services....127
Heavy Minerals Co.....101
High Voltage Engineering Corp.....109
Hoke, Inc..... 99
International Nickel Company, Inc..... 52
Kaiser Engineers..... 15
Kintel (Kay Lab)..... 88
Kidde Nuclear Laboratories, Inc., Walter..... 97
Kollmorgen Optical Corp...121
Leeds & Northrup Co..... 43
Leighton Laboratories, H. W. 99
Lennard Co., Inc., P. M....127
Lindsay Chemical Co..... 86
Lithium Corporation of America, Inc..... 51
Los Alamos Scientific Laboratory 81
Martin Co., Glenn L..... 96
McGraw-Hill Book Co., Inc. 107, 126
Merck & Co. Limited.....122
Metal Hydrides, Inc.....127
Metals Disintegrating Company, Inc.....136
Minneapolis-Honeywell Regulator Co., Industrial Div. 4th cover
NRD Instrument Co. a Subsidiary of Nuclear Corp. of America, Inc.....123
Nuclear Development Corp. of America..... 16
Nuclear-Chicago Corp..... 36
Nuclear Enterprises Ltd....120
Nuclear Measurements Corp. 134
Nuclear Science & Engineering Corp. Subsidiary of Norden-Ketay Corp.....127
Nuclear Systems A Division of the Budd Company.. 12
Nucleonics.....48, 49
Packard Instrument Company.....136
Penberthy Instrument Co...122
Purolator Products, Inc..44, 45

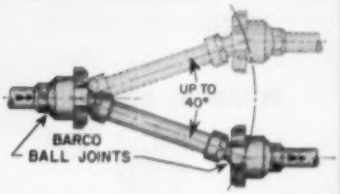
Here's How to Make Safe

COOLING LINE CONNECTIONS

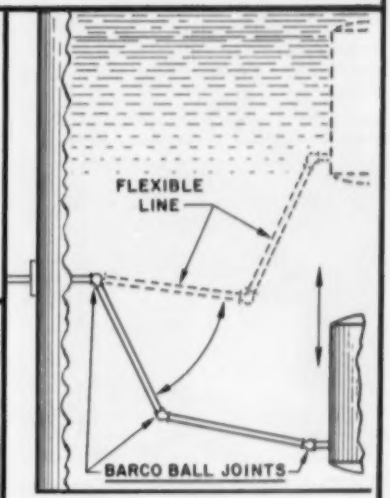
to Moving Reactor Components



ONE JOINT—Provides for angular motion or positioning of piping in any plane.



TWO JOINTS—This arrangement provides for piping alignment or simple flexible connection.



THREE JOINTS—This schematic diagram shows how "dog leg" piping assembly permits vertical movement of large equipment.

Barco Flexible Ball Joints for Nuclear Projects

CERTAIN distinctive characteristics and features make Barco Flexible Ball Joints particularly well-suited for many nuclear energy applications:

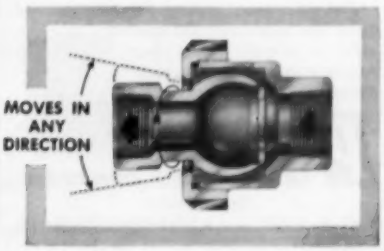
1. Easy to engineer joints into piping to provide for any degree of flexibility, expansion, or movement required.
2. Seals unaffected by radioactivity.
3. All-metal construction. No ball bearings. No lubrication required. Special metals can be specified.
4. Basic design is pressure sealing against leakage and self-adjusting for wear.
5. Maximum safety for virtually any pressure and temperature conditions.
6. Usually no deterioration due to normal operation. Special activities may require special materials.
7. Special flexible joints for conveying fluids at low temperatures down to −300°F. Also high temperature designs up to +1000°F.

For information and recommendations on how to select, specify, and use Barco Joints, address letter to:

BARCO

BARCO MANUFACTURING CO.

567H NORTH HOUGH STREET
BARRINGTON, ILLINOIS



INDUSTRIAL APPLICATIONS OF RADIOISOTOPES WITH THE NEW AUTOMATIC TRI-CARB SPECTROMETER

Tracer Research involving industrial organic compounds — oil and gasoline, solvents, pharmaceuticals, plastics.

Ground Water Studies—large scale water distribution problems, such as pollution and waste disposal.

Large Scale Tagging of plant operation with safety and economy of radioactive materials.

Tri-Carb Liquid Scintillation Counting has opened many new possibilities for industrial applications of radioisotopes by making low level counting of soft beta emitters a simple routine procedure. Consider the following facts to see how this method might be applied to your own work.

Every single organic compound can be uniquely identified with the radioactive isotopes of hydrogen and carbon. These isotopes . . . Tritium and Carbon-14 . . . are readily available and simple to use. They emit very soft beta radiation which cannot penetrate even a thin glass container. Other common soft beta emitters that are now being successfully used in industrial applications are Sulphur-35 and Calcium-45.

Although the Tri-Carb Liquid Scintillation Spectrometer is sensitive enough to be used for natural radiocarbon dating of preserved organic materials that are over 40,000 years old, it is still simple enough to be used for counting hundreds of ordinary samples per day. Obviously the possibilities for practical industrial applications of radioactive tracers are greatly enhanced now that measuring equipment with this inherent sensitivity is available for routine use. Costs, safety, etc., cease to be limiting factors, and even the labeling of consumer products becomes a practical consideration.

For additional general information request Bulletin 314. For specific information on your requirements, provide application details.

Packard
INSTRUMENT COMPANY
Department B
P. O. Box 428 • LA GRANGE, ILLINOIS

GAMMA SHIELDING MATERIALS

BARITE
Crushed—to specification
Ground—95% minus 325 mesh

LEAD
Powder-fineness ranges
40%-50% minus 325 mesh

IRON
Shot and Grit
Graded to specification

*

Inquiries for Metal Powders of all types solicited

METALS DISINTEGRATING COMPANY, INC.
ELIZABETH, NEW JERSEY

World's largest manufacturer of finely divided metals

SCINTILLATOR SOLUTIONS

Lithium, Cadmium
Gadolinium, Lead, Bismuth
Mercury, Uranium

We specialize in the preparation of solutions of high optical transmittance for use in large scintillation counters

Address Inquiries to

A. R. RONZIO, Ph.D., Director

RADIOLOGICAL RESEARCH INSTITUTE, INC.
663 Lipan St.,
Denver 4, Colorado

Radiation Counter Laboratories, Inc. 29
Radiation Instrument Co. . . 120
Radiation Instrument Development Laboratory 83
Radiological Research Institute, Inc. 136
Sargent & Lundy Engineers . 7
Searchlight Section . . . 127–133
Sylvania-Corning Nuclear Corp. 33
Technical Associates 87
Technical Operations, Incorporated 92
Tracerlab, Inc. 30
Tullamore Electronic Laboratory 114
Tube Turns 9
Twentieth Century Electronics Ltd. 97
U. S. Industrial Chemicals Co. Div. of National Distillers and Chemical Corp. 37
United States Radium Corp. 115
Victoreen Instrument Company 119
Vitro Corporation of America 89
Wah Chang Corporation . . 13
Westinghouse Electric Corp. 100, 118
Where To Buy 127

PROFESSIONAL SERVICES 133

CLASSIFIED ADVERTISING

F. J. Eberle, Business Mgr.

EMPLOYMENT OPPORTUNITIES 127–133
EQUIPMENT (Used or Surplus New)
For Sale 133
SPECIAL SERVICES 127
Argonne National Laboratory 129
Atomic Power Development Associates Inc. 130
Bethlehem Steel Co. 132
Continental Can Co., Inc. 130
Fidelity Personnel Service 127
General Electric Co.
Cincinnati, Ohio 128
Idaho Falls, Idaho 128
Schenectady, New York 133
Internuclear Co. 130
M. R. Co., The 133
Marquardt Aircraft Corp. 128
Minneapolis Honeywell Regulator Co., Brown Instruments Div. 131
Saskatchewan Dept. of Public Health. 127
Southern Research Institute 132
Westinghouse Electric Corp. 130

This index is published as a service. Every care is taken to make it accurate, but NUCLEONICS assumes no responsibility for errors or omissions.

MODEL 255S

NEW *Baird-Atomic Amplifier*

for maximum gain stability in proportional counting

Developed exclusively by Baird-Atomic, the Model 255S Amplifier is designed for use with Gas-Flow Counters operating in the proportional counting region. A typical proportional counting system includes: a Microthin window flow counter in a lead-shield, a Model 255S Amplifier, a scaler of the TEN-HUNDRED series, and a dual-purpose automatic timer.

Power for Model 255S can be obtained from any of the scalers in the TEN-HUNDRED series. The high voltage for the detector can be supplied from either a scaler or a separate high voltage supply.

OUTSTANDING FEATURES OF MODEL 255S:

Non-overloading	Built-in delay line
Stable	Low noise

SPECIFICATIONS:

Gain . . . approx. 300
Input . . . from proportional counter
Output . . . −6v, 2 μsec duration (approx.)
Noise at output . . . 60 cps −50mv
Random noise . . . 50mv
Delay line . . . built-in delay line for pulse shaping
Filter . . . built-in double HV filter
Power requirement . . . up to 5000v (depends on counting gas used)

Complete specifications and price available on request—write for Bulletin 255-1.

SALES REPRESENTATIVES

Atomic Associates, Inc. — New York, Boston, Philadelphia
Atomic-Western — Los Angeles, San Francisco
W. A. Brown & Associates, Inc. — Alexandria, Va., Indian River City, Fla.
Packard Instrument Co. — LaGrange, Ill.
H. E. Ranford Co. — Pittsburgh
Canadian Marconi Co. — Montreal, Toronto, Winnipeg, Vancouver, Halifax
Overseas — Australia, Belgium, Denmark, France, India, Israel, Italy, Japan, Mexico, Norway, Puerto Rico, Sweden, Switzerland

BAIRD ATOMIC

Baird–Atomic, Inc.

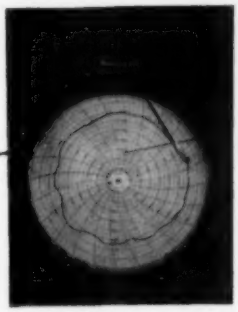
33 UNIVERSITY ROAD, CAMBRIDGE 38, MASSACHUSETTS

ElectroniK recorders . . . with special scales for nuclear process variables.

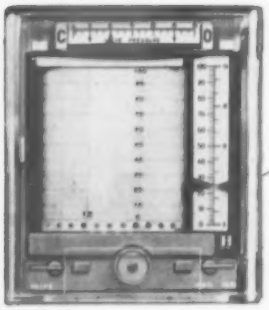
MegopaK thermocouple wire . . . designed for fuel element temperatures in nuclear installations.

Safety amplifiers . . . one of eight special units for reactor control.

from ONE source



Pressure gages . . . for coolant flow, monitoring, and other applications.



Tel-O-Set miniature instruments . . . for use on graphic panels or to save space.

Three-mode controllers . . . matched to reactor characteristics.

. . . reactor instrumentation for every need

What are your instrumentation requirements—a single instrument . . . a packaged nuclear reactor control system? You can place undivided responsibility with Honeywell for everything from initial specifications to complete installation and startup.

From this one source, the world's largest instrument manufacturer, you also receive expert engineering assistance in application and maintenance . . . and prompt, efficient service from a branch office near you.

Your local Honeywell sales engineer will be glad to help you select the reactor instrumentation you need. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

Honeywell

H HONEYWELL

First in Controls